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EVALUATION PROCEDURE FOR LINEAR ARRAY PHOTOSENSITIVE DETECTORS
APPLICATION TO THOMSON CSF TH7805

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EVALUATION PROCEDURE FOR LINEAR ARRAY PHOTOSENSITIVE DETECTORS APPLICATION TO THOMSON CSF TH7805

by

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ABSTRACT

//Photosensitive detectors play a predominant role in data collection procedures of optical signal processing applications. They constitute the transition stage between the optical and electrical portions of the experiment. Among these detectors, linear array image sensors are widely used when high resolution measurements are needed. However, before incorporating these detectors into an experiment, it is important to evaluate their performances. In this report, different tests are presented to allow a characterization of the performance of linear image sensors. The procedures focus on four different aspects of the detectors: the signal structure (including the noise), the sensitivity profile of the detector and the elements and the dynamic range of the detector. As an example, the linear array image sensor TH7805 from Thomson CSF is analyzed.//

RESUME

Les détecteurs photosensibles jouent un rôle prédominant dans le processus de prises de données des applications optiques de traitement de signaux. Ils représentent l'étape de transition entre les parties optique et électrique de l'expérience. Parmi ces détecteurs, les barrettes linéaires de détection optique sont très utilisées lorsque des mesures à haute résolution sont requises. Cependant, avant d'intégrer ces détecteurs à l'intérieur de systèmes expérimentaux, il est important d'évaluer leur rendement. Dans ce rapport, diverses méthodes d'évaluation sont présentées pour caractériser le rendement des capteurs linéaires optiques. Les procédures d'évaluation font état de quatre aspects des détecteurs: la structure du signal (incluant le bruit), les profiles de sensibilité du détecteur ainsi que des éléments et le domaine dynamique du détecteur. A titre d'exemple, la barrette de détection optique TH7805 de Thomson CSF est analysée.

EXECUTIVE SUMMARY

Photosensitive detectors represent an important component in systems designed for optical signal processing. They convert the information carried by the light signal into electrical signal to allow further processing of different characteristics of the system under study. They constitute the transition stage between the optical and the electrical portions of the system.

Among the different implementations of photosensitive detectors, linear image sensors represent an important category. These sensors allow a high spatial resolution analysis of the light signal. They are formed from a number of independent photodiodes closely aligned on a linear axis. Each photodiode collects a portion of the information carried by the light signal and transmits a corresponding electrical signal on the output line for further analysis. Since linear image sensors are used as measurement devices, it is important to be able to characterize their performance to be sure they can meet the requirements of the experiment.

In this report, procedures for the evaluation of the performance of linear image sensors are given. Different parameters such as signal structure, sensitivity profile and dynamic range are evaluated. Although the analysis is based on a specific detector, the Thomson CSF TH7805, the procedures remain general enough to be applicable to other types of linear photosensors.

The discussion is initiated with a general description of linear image sensors and of the overall experimental set-up used to evaluate the performance of detectors. Some specific characteristics of the detector under test are also presented. This discussion is followed by the description of the analysis of the signal structure of the linear array detector. Typical output signals, depicting internal noise, threshold detection, operational signal and saturation signal, are presented. It is found that the detector under test suffers from a high level of dark noise due to a power leakage of the timing module into the detection signal. Other technical details such as the width of a detection sample on the output signal, amplitude and frequency spectrum of the dark signal are also discussed.

The sensitivity profile of the detector is then analyzed. The response of a number of elements to a constant illumination level is measured and plotted. It is found that the response is not uniform throughout the different elements of the detector. A variation of ±10% in the sensitivity level of the different elements of the detector is observed. The manufacturer specified ±5%. It is suggested that a weighting factor be used in actual experiments. The weighting factor may be incorporated either as software manipulation on the output signal or by a modification of the illumination distribution level.

Following is an analysis of the sensitivity profile of the elements themselves. An analysis of their power of resolution. The profiles are shown as a relation between the voltage response of the detector's elements and the horizontal position of the incident focussed beam. It is observed that the profile of each element takes the form of a bell shape. The high sensitivity area

of an element spans over approximately $10\mu m$. The sensitivity quickly drops off as the light beam is focused outside that sensitive area. At a position $13\mu m$ from the centre of an element, the voltage response is reduced to the noise level, approximately $13\mu m$ lower. These figures corresponds to the specifications given by the manufacturer.

The dynamic range of the detector is then investigated. The evaluation is based on a ratio of the incident laser power to the voltage response of the elements of the detector. The dynamic range of the detector is evaluated under three different integration time. It is observed that the output signal voltage is proportional to the incident laser power and consequently to the energy detected. From the analysis performed, it is found that the dynamic range of the detector is approximately 21 dB (measured as the ratio of the incident laser power level required to saturate the detector over the incident laser power level required to obtain a signal just above threshold). This value contrasts with the 37.8 dB claimed by the manufacturer. The dark noise level, which is measured to be much higher than the specification, and the methods of calculation of the dynamic range (the manufacturer used a ratio of saturation voltage over the dark noise voltage), may explain the difference.

Comparing the results obtained by performing the experiments described in this report to those presented by the manufacturer, it is found that in many instances the values differ. The performance measured is much lower than the one suggested by the manufacturer. A major factor contributing to this degraded performance is the electronic leakage of the system clock into the output signal stream. The linear array TH7805 would probably benefit from the use of an improved driver module.

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1.0 INTRODUCTION

Photosensitive detectors represent an important component in systems designed for optical signal processing. They convert the information carried by the light signal into electrical signal to allow further processing of different characteristics of the system under study. They constitute the transition stage between the optical and the electrical portions of the system.

Among the different implementations of photosensitive detectors, linear image sensors represent an important category. These sensors allow a high spatial resolution analysis of the light signal. They are formed from a number of independent photodiodes closely aligned on a linear axis. Each photodiode collects a portion of the information carried by the light signal and transmits a corresponding electrical signal on the output line for further analysis. Since linear image sensors are used as measurement devices, it is important to be able to characterize their performance to be sure they can meet the requirements of the experiment. Different parameters such as signal structure, sensitivity profile and dynamic range must be evaluated as part of this characterization process.

In this report, procedures for the evaluation of the performance of linear image sensors are given. Although the analysis is based on a specific detector, the Thomson CSF TH7805, the procedures remain general enough to be applicable to other types of linear photosensors. In Chapter 2, a general description of linear image sensors is given as well as some specific characteristics of the CSF TH7805 under test. Also given in Chapter 2 is the overall experimental set-up used to evaluate the performance of detectors. The purpose of Chapter 3 is to identify aspects of the detector output signal which are important to consider when selecting an image sensor for a specific application. Chapters 4 and 5 serve to define procedures to evaluate sensitivity profiles of the detector array and of the individual elements. The dynamic range of the detector is investigated in Chapter 6. Finally in Chapter 7, the performance characteristics evaluated during the report are compared to those given by the manufacturer.

2.0 GENERAL

2.1 Linear array detectors

2.1.1 General description

Linear image sensors are composed of a linear array of closely spaced photosensitive diodes. To allow high resolution detection, the size of the diodes must be minimized as well as the space between adjacent diodes. Different manufacturing implementations are possible to achieve this goal. Solid state implanted P-N junction diodes are one popular type of sensor. Each element of the detector array integrates during a certain preset time a photocurrent generated by the incident light energy. A charge packet proportional to the total energy detected builds up in the diode during that time. The charge packet is transferred to a buffer, usually a charged coupled device (CCD) analog shift register, for output transmission. The output signal consists of a serial transmission of voltage levels, each one characterizing the energy integrated by a particular element.

2.1.2 Description of Thomson CSF TH7805

The evaluation procedures described in this report will use the Thomson CSF TH7805 charged coupled device as a model for the analysis of linear array image sensors. Associated with the TH7805 detector is a driver module on which the electronics necessary for proper operation is mounted. The driver module, THX1061, is also from Thomson CSF. Fig. 1 and 2 display the image sensor and the driver module.

The CCD TH7805 is a solid state image sensor, composed of a linear array of 2048 implanted P-N junction photodiodes. The photodiodes present a sensitive area of 10 μm wide by 13 μm high and are spaced 13μm apart when measured from centre to centre. The length of the array is 26.6 mm. For this detector, the available integration times range from 100 μs to 10 ms. Two registers are used to read the charges generated by the elements of the array. One of the register receives the charges generated by the "odd number" elements (channel A) while the other register processes the "even number" elements (channel B). The video signals from both registers are interleaved in time to facilitate external multiplexing.

In Table 1, a summary of the main performance characteristics of the TH7805 detector is given. The summary is based on the manufacturer specifications [1]. Throughout this report, experiments to measure the parameters given in Table 1 will be described. A comparison between the manufacturer's specification and the results of the experiments will also be given.

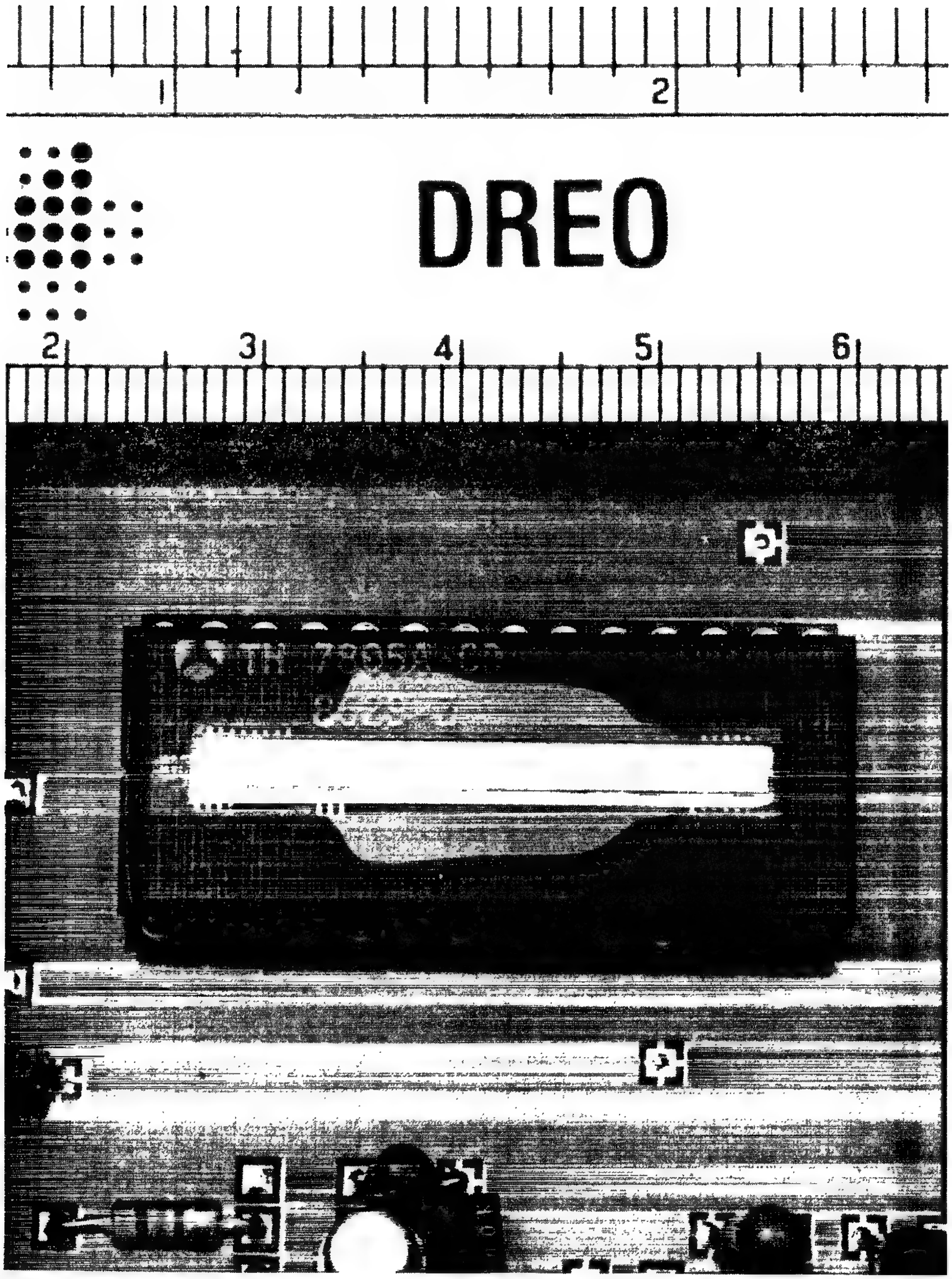

Fig. 1 Photodetector array analyzed in this report. Thomson CSF TH7805.

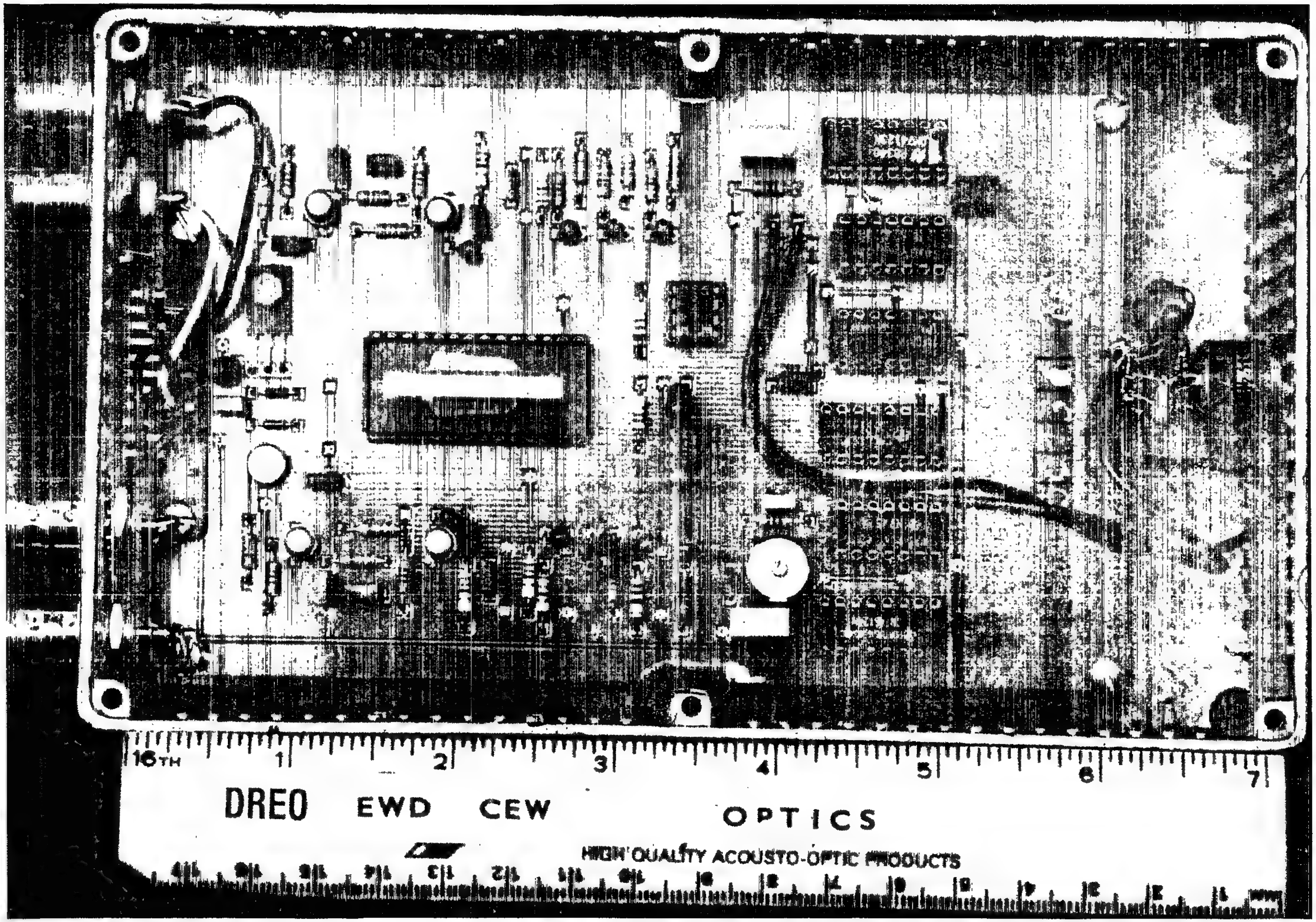

Fig. 2 Photodetector array mounted on the printed circuit board and enclosed in a chassis.

THOMSON CSF TH7805

GENERAL SPECIFICATIONS

Number of photodiodes	2048
Size of elements	13 μm X 13 μm
Size of sensitive portion	10 μm X 13 μm
Output data rate (1msec integration time)	5 MHz
RMS noise in darkness	0.4 mV
Average dark signal	0.5 mV
Dark signal non-uniformity	0.5 mV
Signal response non-uniformity	± 5%
Difference between responses of channel A and B	5%
Saturation of output voltage	1.7 V to 4.5 V
Saturation exposure	0.38 μJ/cm^2
Dynamic range (relative to RMS noise)	37.78 dB

Table 1 General characteristics of the Thomson CSF TH7805

2.2 Experimental set-up

The following paragraphs serve to describe the experimentation set-up used to characterize linear image sensors. The various components are identified and some important aspects of their implementation are discussed. The description is based on Fig. 3 and 4 which show a diagram of a typical set-up and a photograph of the actual experimentation test bed used for this report.

2.2.1 Light source. The light source represents an important element of the system and it should be chosen with care. Some aspects to consider are:

a. the wavelength of the laser source must be representative of the work to be performed by the detector since the sensitivity of most detectors is wavelength dependent,

b. the maximum power of the source must be sufficient to saturate the elements of the sensor,

c. the output power of the laser source should be as constant in time as possible.

Since variations of the incident light intensity are reflected in variations of the detector's output signal level, it is advisable to use a voltage regulator on the power feed line of the laser in order to keep the output laser power as constant as possible.

In the experiments described here, a 5 mW helium-neon Spectra Physics, model 135 linearly polarized laser was used.

2.2.2 Attenuation stage. Two stages of attenuation are used. A variable NRC attenuator is placed directly at the output of the laser to allow fine tuning of the light intensity. The second stage, used for coarse tuning and consisting of fixed neutral density filters, is also mounted before the collimator.

It is advisable to mount the attenuators in front of the collimator in order to minimize scattering of the laser beam induced by the filters (or any component introduced in the path of the laser beam). Phase errors produced by neutral densities would also be minimized if the filters were placed directly in the unexpended laser beam.

2.2.3 Collimation stage. To position the laser beam with a high degree of precision, it is important that the dimensions of the focussed light signal on the sensitive surface of the detector be as small as possible. A collimated beam is used to fill the aperture of the focussing lens in order to minimize the size of the focussed point.

2.2.4 Calibrated detector. To monitor the intensity of the laser beam, a calibrated detector is used. This detector is not associated to any automatic process; its reading is monitored visually by the operator. A beam splitter mirror, tilted to reflect part of the light onto the calibrated detector, is mounted in front of the focussing lens.

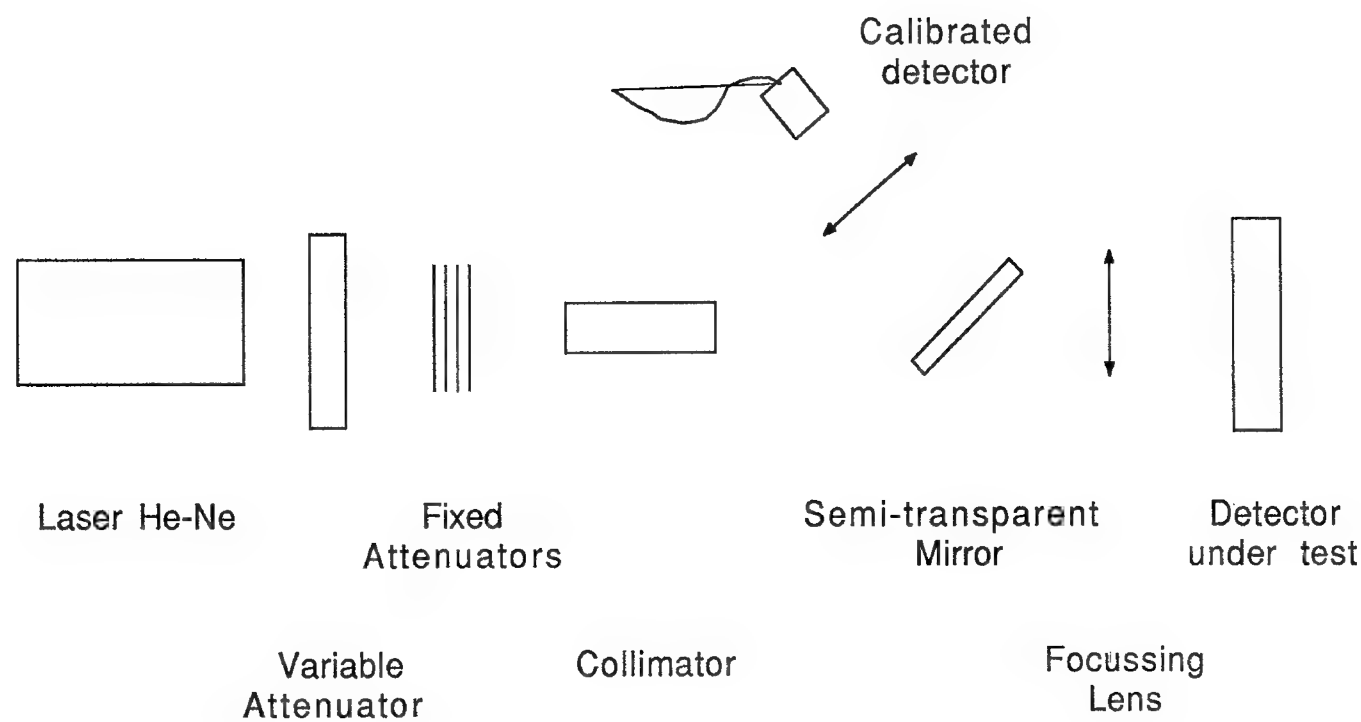

Fig. 3 General configuration of the experiment set-up.

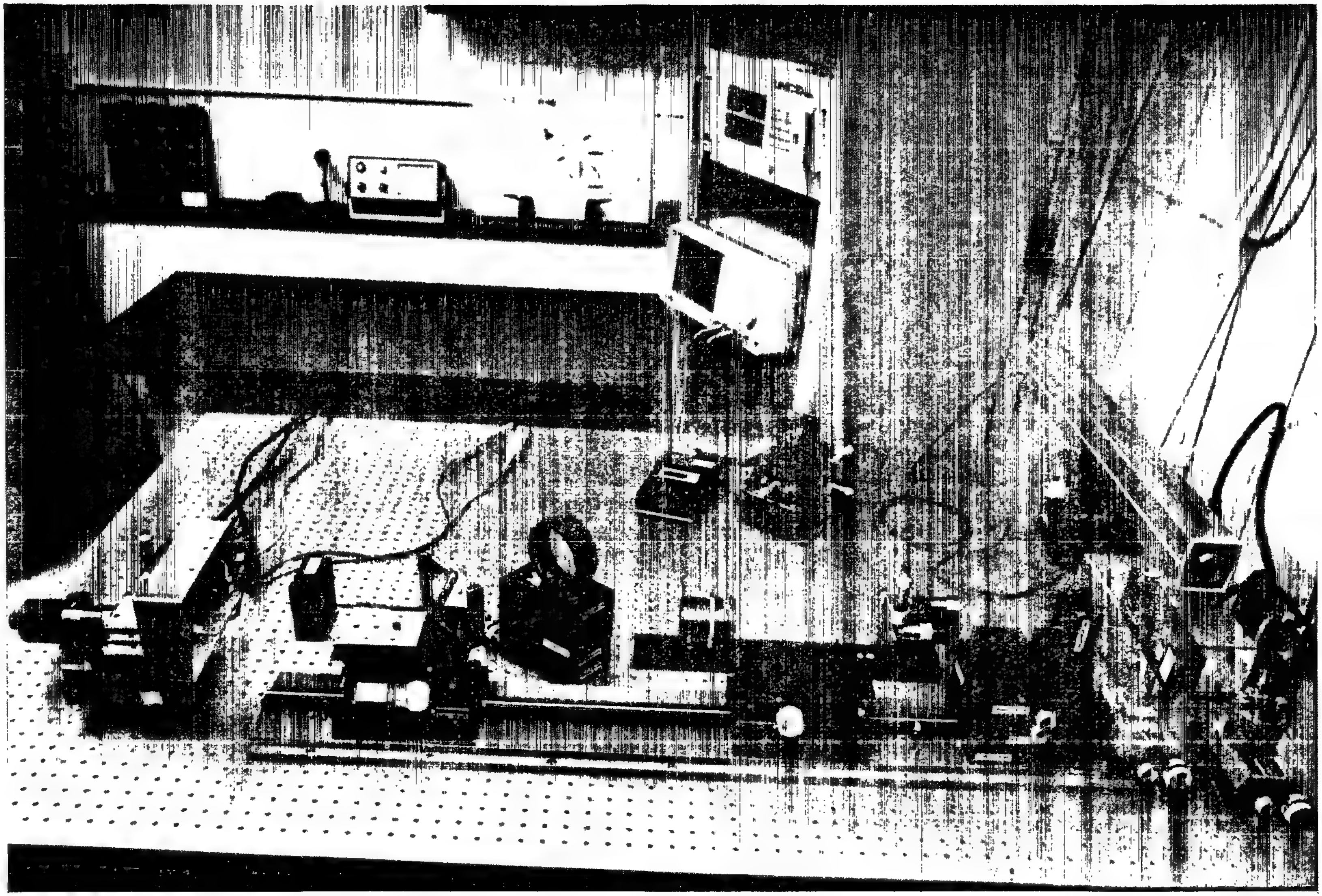

Fig. 4 Actual set-up used for the experiments described in this report.

2.2.5 Focussing lens. The laser beam is focussed on the detector in an area approximately one tenth the size of a photodiode. Two types of lenses are needed and each type is used for specific applications.

a. Cylindrical lens. A cylindrical lens is used to create, in the focal plane, a vertical line whose power level is considered constant across the surface of the element under study. This type of lens is used in most of the testing experiments to facilitate horizontal level adjustments of the detector and consequently reduce possible errors created by slight vertical displacements of the detector array relative to the illumination pattern.

b. Spherical lens. A spherical lens is used to concentrate the laser light energy in a small area less than the element size at the focal plane. This type of lens is used when monitoring the energy incident on the element under study is important, as in the case of dynamic range analysis.

In the experiments described here, the cylindrical lens produces a vertical line of 3 μm wide (measured between first nulls). The spherical lens gives a focussed point of 2 μm in diameter. The measurements were performed using a calibrated microscope.

2.2.6 Detector under test. The detector under test (Fig. 1 and 2) is mounted at the focal plane of the focussing lens. Scanning of the different elements of the detector is accomplished by moving the detector along the horizontal axis, perpendicular to the laser beam. A computer controlled motorized translation stage is used to move the detector. For every experiment, the illumination beam is kept stationary.

2.2.7 Translation stages. To ease the process of horizontal displacements as well as focal adjustments, the detector is mounted on a computer driven X-Z translator. A Y-plane translator is also used to keep the sensitive area of the detector in the laser beam. This Y-plane translator is essential since an horizontal motion may produce a small vertical displacement of the array if the linear array is not perfectly horizontally levelled. As the detector is translated horizontally, the elements would move out of the focussed beam area (in the vertical plane) resulting in a variation of the recorded signal from one element. As mentioned, this effect is alleviated when the focussed beam is produced from a cylindrical lens.

To achieve high resolution samplings on each element, the step size of the translators must be smaller than the size of the elements of the detector. This becomes particularly important in the analysis of the sensitivity profile. The step resolution of the Unidex II translator stages used is 1.3 μm.

2.2.8 Oscilloscope. Each output channel of the detector module is connected to a 1 Megohms input port of an HP54100A/D oscilloscope. The digitizing oscilloscope receives each element's response, analyzes it and sends the desired parameters to the computer for further processing.

2.2.9 Computer. Since most of the analysis involves repetitive actions, a high degree of automation is used. Translation stage movements, data acquisition, recording of the output signals, presentation of the results are all controlled automatically. For this report, an IBM AT personnel computer is used.

2.2.10 Software package. The computer programs, used to automate the experiments are presented in Annex A. They are written in the IBM Basic language [2]. The communication mode between the computer, the oscilloscope and the translators is based on the IBM General Purpose Interface Bus (GPIB) control protocol [3]. The following gives a brief description of the programs.

a. Peakval: Determines the timing position and the value of maximum amplitude point of the signal in channel A or B of the oscilloscope HP54100A/D,

b. Profile: Determines the sensitivity profile of the elements of a linear array photosensitive detector.

3.0 SIGNAL CHARACTERISTICS

A first step in the evaluation of the performance characteristics of a detector is to undertake the analysis of the output signal characteristics. Aspects to consider are:

a. structure of a typical output signal,

b. means of retrieving the information produced by each element,

c. minimum and maximum output signal levels that can be expected,

d. importance of the noise introduced by the system and ways to reduce it,

e. other factors which might affect the precision of the measurements, such as thermal expansion and vibrations.

A thorough understanding of these points prior to proceeding further in the evaluation of the detector may prevent false interpretation of the data. It will also permit the adaptation of the analysis of the results to the particular detector under test. In this chapter, experiments are described to evaluate the different aspects related to the signal characteristics. The analysis is based on the detector TH7805. In section 3.1, aspects related to the structure of the output signal are reported while in section 3.2 an analysis of the dark signal is undertaken.

3.1 Output signal

As mentioned in Chapter 2, each element generates a charge packet proportional to the laser energy incident during the integration time. Serial access to the element response is provided by an analog shift register whose output samples have voltages proportional to the size of the charge packets. The samples are transmitted alternately by each channel according to the parity of the element (pulses from odd and even numbered elements are transmitted through channel A and B respectively).

Fig. 5a and 5b show typical output signals from channels A and B respectively, resulting when only one element of the detector is illuminated. Although an integration time of 1 ms was selected for these measurements, similar curves can be obtained for other integration times. In both figures, a single pulse, depicting the response sample of an illuminated element, can be clearly identified. It is seen that the voltage level associated to a sample is held for approximately 0.6 μs. However, a secondary peak of smaller amplitude appears in the middle of the sample value. The presence of a secondary peak is abnormal in the output signal of a good "sample and hold" device for which the voltage value of the sample remains constant throughout the pulse time. Since this secondary peak occurs in the middle of each pulse, it is suspected that it is

created by electronic leakage from the clock pulse triggering the output sample of the other channel. (Remember that the output signals from the two channels are interleaved in time). Moreover the amplitude of this secondary peak is not modified by a variation of the illumination intensity as it is the case for the amplitude of the sample itself. Fig. 6 and 7 show the output signal for illumination levels at the threshold and saturation levels respectively. For small illumination levels, the output voltage level is very sensitive to the sampling time as seen in Fig. 5 and 6. At saturation, the variations in the voltage level of the sample created by the secondary peak are relatively small. The sampling time is then less critical.

It has been measured that the timing separation from the centre of one sample to the centre of the adjacent one in the same channel is approximately 0.70μs. However in some occasions the timing separation between samples presents a different value. Tables 2 a), b) and c) show, for three different sets of elements, the timing positions of the peak value of consecutive samples. The fact that the timing separations between samples are not always identical may be explained by the presence of the secondary peak which corrupts the sample voltage, modifying the timing position of the maximum amplitude of the sample. The value of 0.70 μs measured as the timing separation between adjacent samples of the same channel corresponds to an output data rate in each channel of approximately 1.43 MHz. This leads to an overall detector output data rate of 2.86 MHz. As presented in Table 1, the manufacturer obtained an output data rate of 5 MHz when operating with an integration time of 1 ms. The difference between the value measured during the experiments and the value given by the manufacturer should have no effect on the results of the experiments since in both instances, the data rate is high enough to allow all samples to be outputted within the integration time of 1 ms.

The lower limit of detectability for an element is obtained when the amplitude of the transmitted pulse emerges from the noise floor and may be identified either by the operator or from computerized analysis. Fig. 6a and 6b show the minimum detectable voltage or threshold value. The value shown here was set by the operator. The laser power associated to this value is taken as the threshold of the dynamic range of the detector. It is to be noted that this lower limit greatly depends on the noise level. Reduction of the noise level would allow a reduction of the detectability threshold and consequently the dynamic range would increase.

On the other hand, if the energy absorbed by an element exceeds a certain level, the detector saturates. For higher energy, the output voltage level would remain at the saturation level. Fig. 7a and 7b illustrate the signal recorded when one element reaches saturation. The laser power, incident on the element and associated with the saturation level is taken as the higher limit of the dynamic range of the detector.

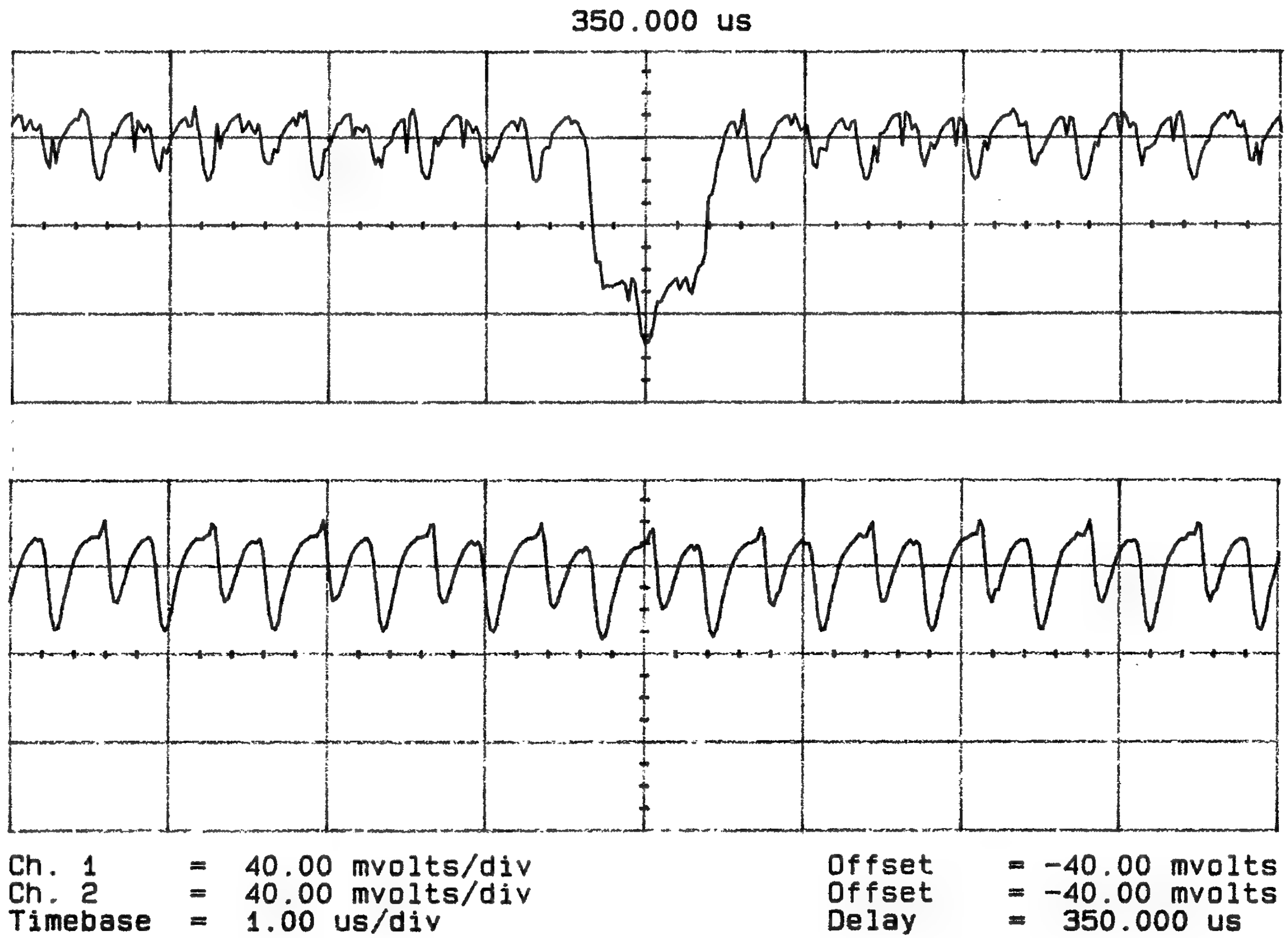

Fig. 5a Output signal of channel A (Top) and channel B (bottom) when only one element of channel A is illuminated. Integration time: 1 ms.

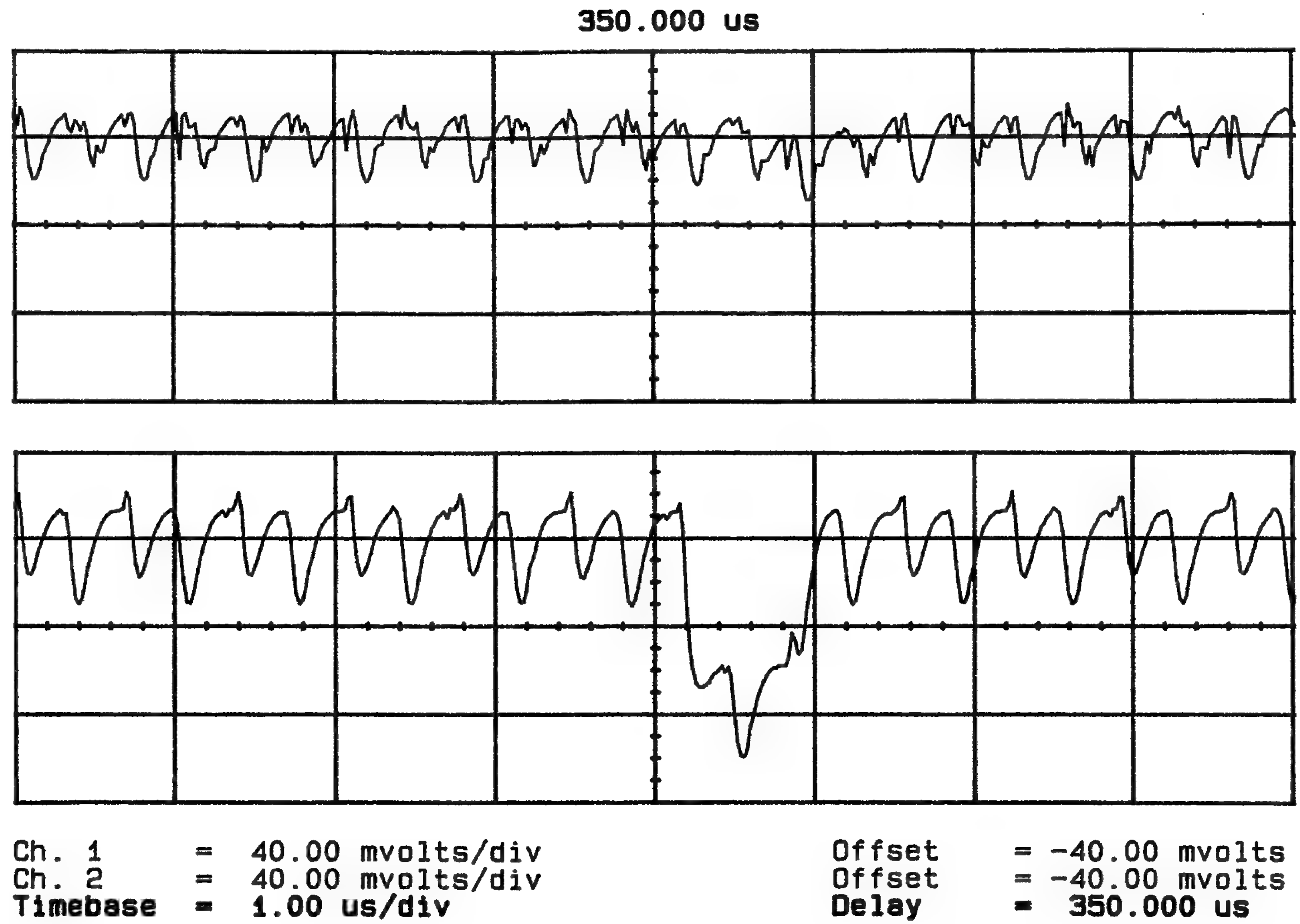

Fig. 5b Output signal of channel A (Top) and channel B (bottom) when only one element of channel B is illuminated. Integration time: 1 ms.

Element No	Time after trigger (μs)	delta t odd elements (μs)	delta t even elements (μs)
20	17.045	.625	
21	17.436		.703
22	17.670	.703	
23	18.139		.625
24	18.373	.703	
25	18.764		.703
26	19.076	.703	
27	19.467		.703
28	19.779	.503	
29	20.170		.703
30	20.282	.903	
31	20.873		.703
32	21.185	.703	
33	21.576		.703
34	21.888	.703	
35	22.279		.703
36	22.591	.703	
37	22.982		.703
38	23.294	.703	
39	23.685		.703
40	23.997	.625	
41	24.388		.625
42	24.622	.703	
43	25.013		.781
44	25.325	.703	
45	25.794		.625
46	26.028	.703	
47	26.419		.703
48	26.731	.703	
49	27.122		
50	27.434		

Table 2a: Timing uncertainty - elements 20 to 50. The entries show the time position of the maximum intensity of consecutive elements as well as the time difference between adjacent maximums of the same channel.

Element No	Time after trigger (ls)	delta t odd elements (ls)	delta t even elements (ls)
170	69.183	.703	
171	69.574		.703
172	69.886	.625	
173	70.277		.625
174	70.511	.703	
175	70.902		.703
176	71.214	.703	
177	71.605		.703
178	71.917	.703	
179	72.308		.703
180	72.620	.703	
181	73.011		.703
182	73.323	.703	
183	73.714		.703
184	74.026	.703	
185	74.417		.703
186	74.729	.703	
187	75.120		.703
188	75.432	.703	
189	75.823		.703
190	76.135	.703	
191	76.526		.703
192	76.838	.625	
193	77.229		.703
194	77.463	.703	
195	77.932		.625
196	78.166	.703	
197	78.557		.703
198	78.869	.703	
199	79.260		
200	79.572		

Table 2b: Timing uncertainty - elements 170 to 200. The entries show the time position of the maximum intensity of consecutive elements as well as the time difference between adjacent maximums of the same channel.

Element No	Time after trigger (ls)	delta t odd elements (ls)	delta t even elements (ls)
1990	704.723	.700	
1991	705.113		.622
1992	705.423	.620	
1993	705.735		.776
1994	706.043	.780	
1995	706.511		.702
1996	706.823	.700	
1997	707.213		.700
1998	707.523	.622	
1999	707.913		.700
2000	708.145	.778	
2001	708.613		.622
2002	708.923	.620	
2003	709.235		.698
2004	709.543	.700	
2005	709.933		.700
2006	710.243	.700	
2007	710.633		.700
2008	710.943	.700	
2009	711.333		.700
2010	711.643	.700	
2011	712.033		.700
2012	712.343	.700	
2013	712.733		.700
2014	713.043	.700	
2015	713.433		.700
2016	713.743	.700	
2017	714.133		.778
2018	714.443	.702	
2019	714.911		
2020	715.145		

Table 2c: <u>Timing uncertainty - elements 1990 to 2020.</u> The entries show the time position of the maximum intensity of consecutive elements as well as the time difference between adjacent maximums of the same channel.

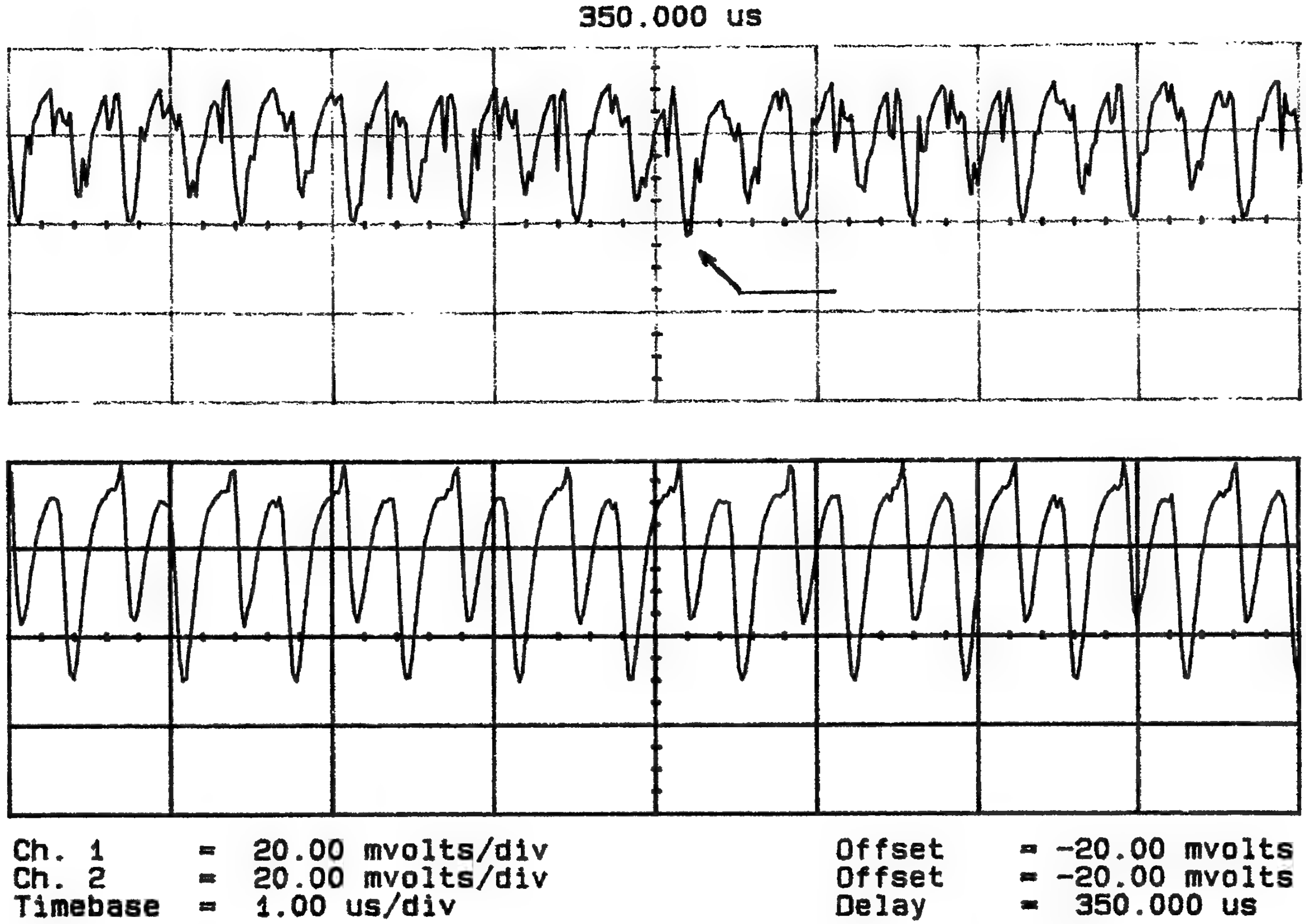

Fig. 6a <u>Threshold detection.</u> An element of channel A (indicated by the arrow) received just enough energy to send a signal level above the noise floor. Integration time: 1 ms.

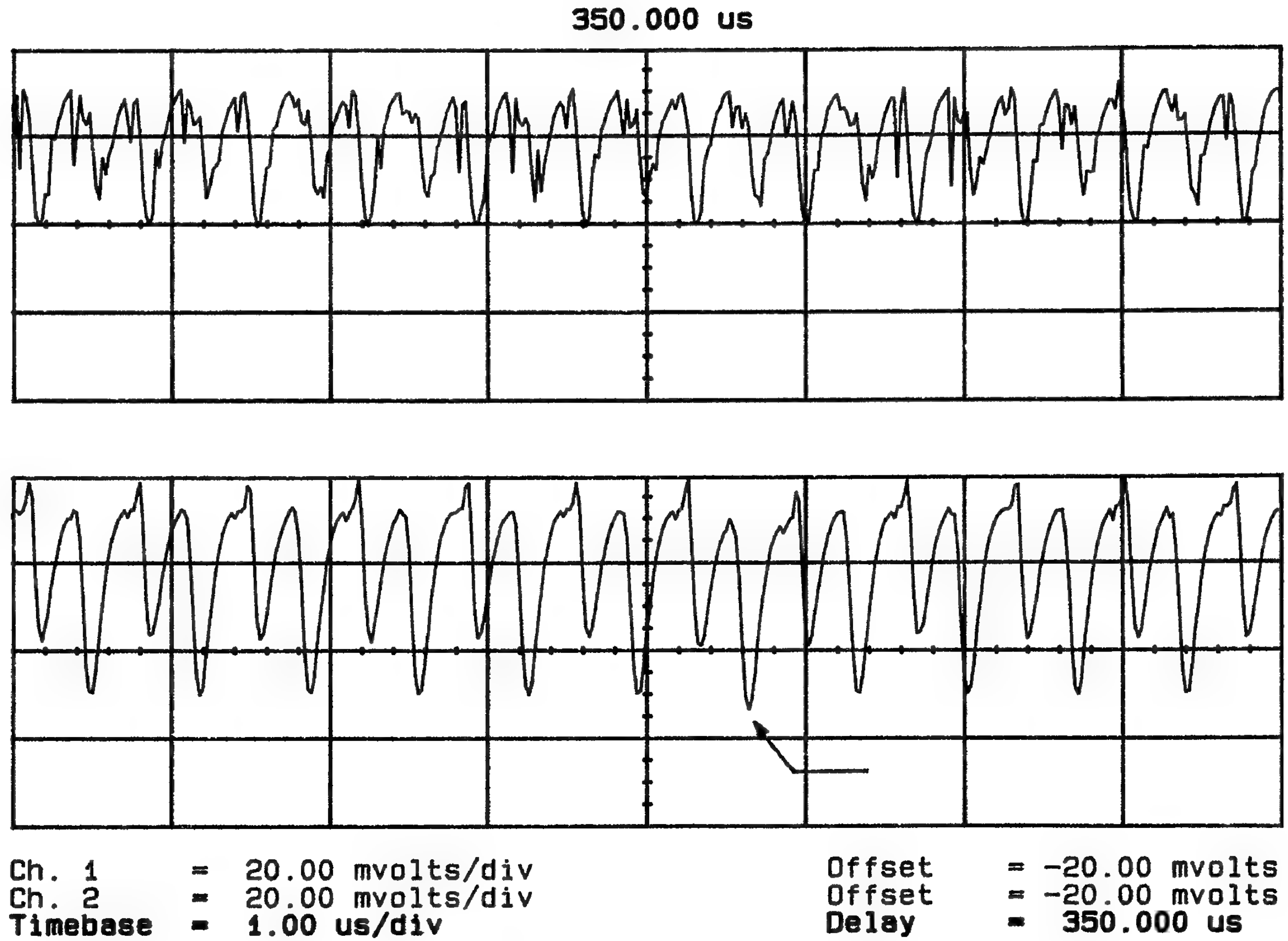

Fig. 6b <u>Threshold detection.</u> An element of channel B (indicated by the arrow) received just enough energy to send a signal level above the noise floor. Integration time: 1 ms.

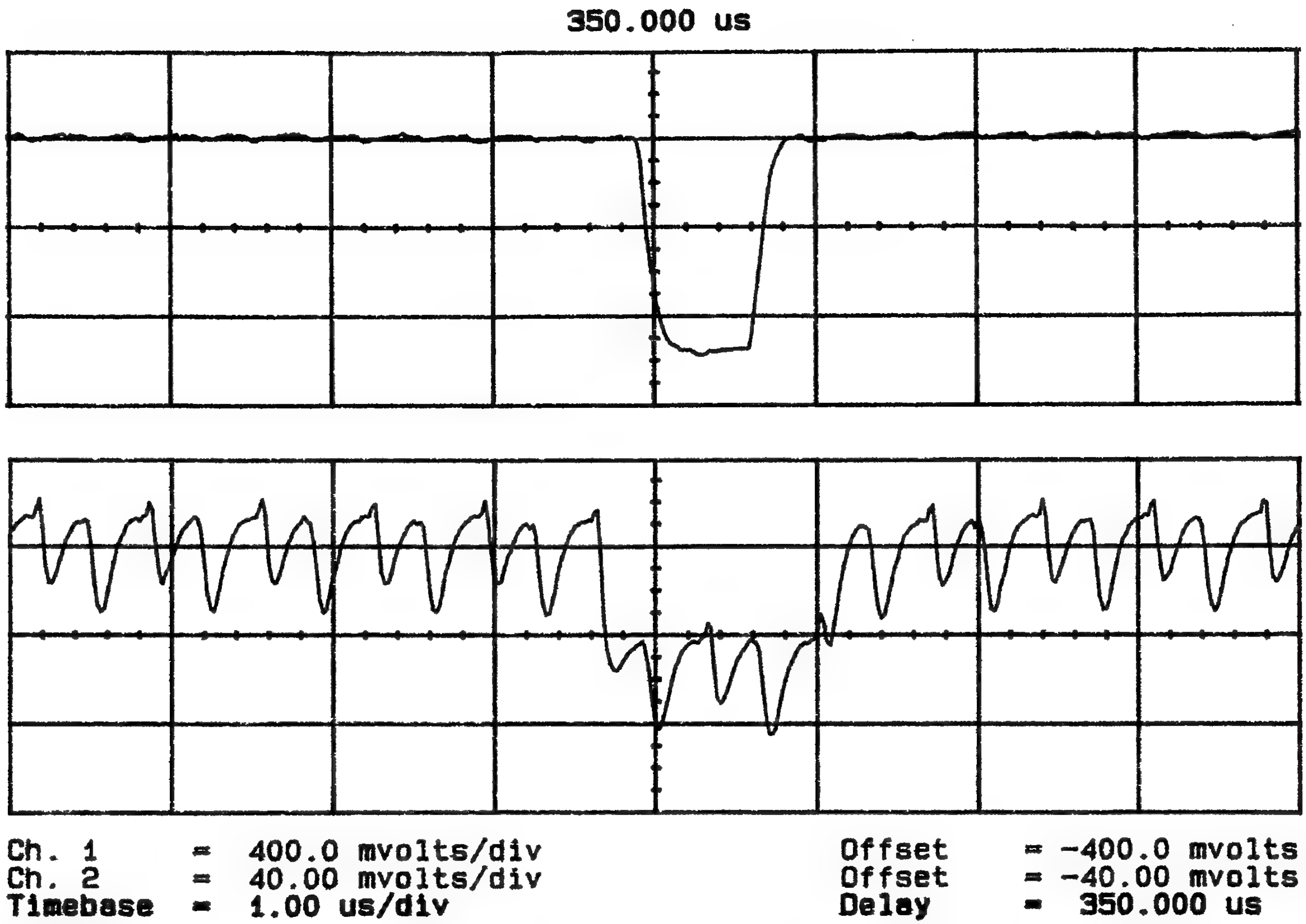

Fig. 7a Saturation level. Element of channel A at the saturation level. Electronic leakage and optical scattering also affected the adjacent elements, in channel B. Integration time: 1ms.

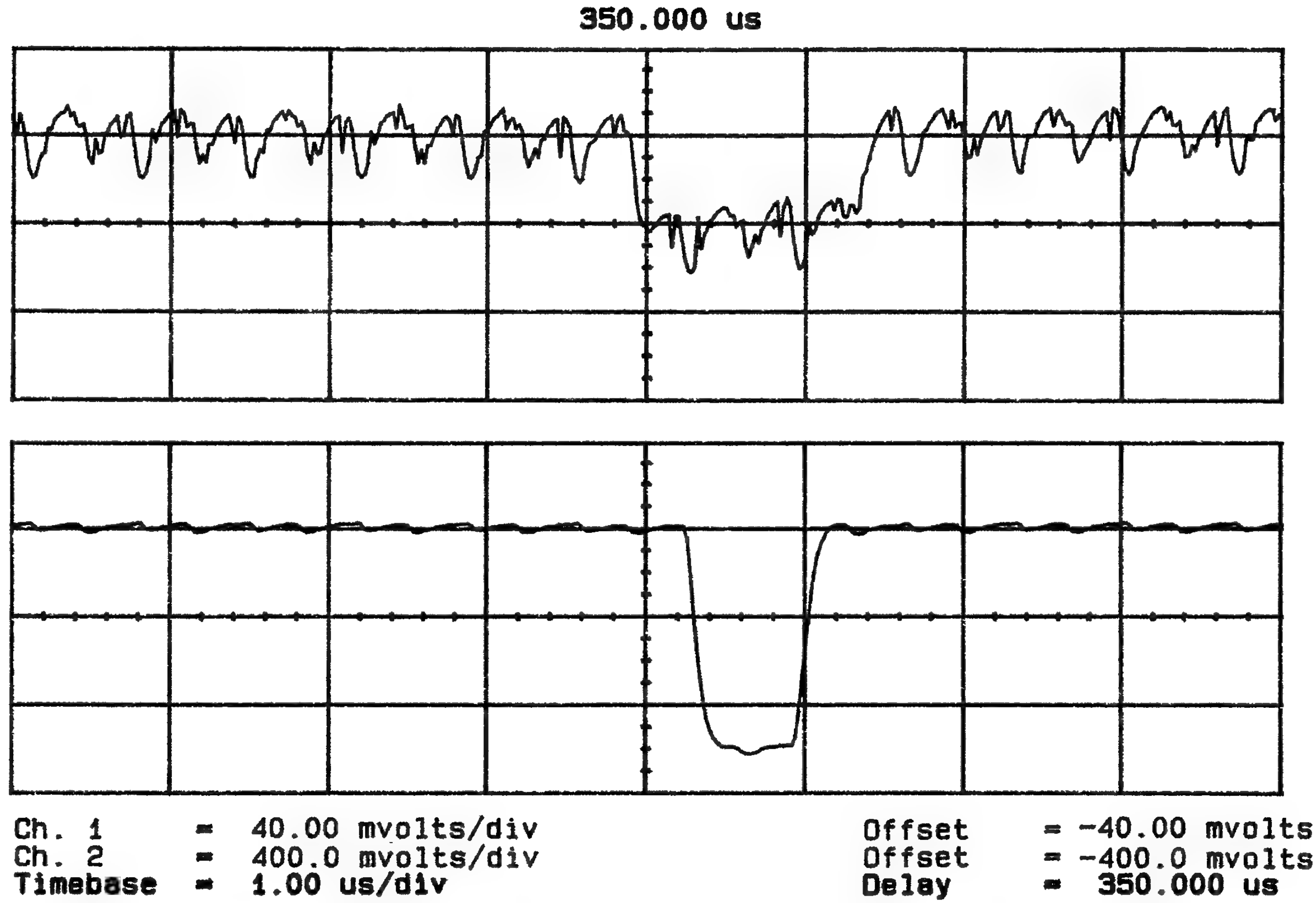

Fig. 7b <u>Saturation level.</u> Element of channel B at the saturation level. Electronic leakage and optical scattering also affected the adjacent elements, in channel A. Integration time: 1ms.

3.2 Internal noise

Internal noise may be defined as corruption of the output signal by components or operations inherent to the driver module and the detector. For example, residual charges in the CCD shift registers or electronic leakages from various components, such as system clock or power lines, may serve to distort the output pulses.

To evaluate the importance of the internal noise level, an analysis of the dark signal is performed. The term "dark signal" describes the output signal of elements in complete darkness. In this condition, the signal structure is free of any contributions from the illumination system. A more accurate evaluation of the internal noise is then obtained. In this section an evaluation of the internal noise level and its implications on the performance of the detector will be discussed.

Fig. 8 shows the dark signal of both channels of the TH7805 for a 1 msec integration time. The figure depicts only a portion, associated to 15 elements, of the total signal. As can be seen, the dark signal does not present a constant voltage level but is corrupted by a periodic signal. This suggests that the residual charges in the CCD may not be the only contributors to the noise signal. In fact the evaluation of the period of the pattern leads to the conclusion that an electronic "leakage" from the detector's internal clock is responsible for most of the amplitude of the noise. This interpretation is reinforced by the fact that for the experiments performed for this report, the level of the noise structure was independent of the integration time. This independence is not a characteristic of the noise contributions due to residual charges in the CCD, which increases with an increase of the integration time. It could be thought that filtering the output signal could reduce the noise level. However, as can be seen in Fig. 9a and 9b, the power spectrum of the dark signal in both channels, as measured with a spectrum analyzer HP8568B is so large that filtering would not be of any benefit.

Computing the average level of the dark signal, one finds a value of approximately 0.4 mV. This value is in accordance with the specifications of 0.5 mV given by the manufacturer (ref. Table 1). However, the measurement of the root mean square (RMS) gives results substantially divergent from the data sheet. The RMS noise of the dark signal is evaluated to be approximately 5 mV for channel A and 13 mV for channel B as opposed to 0.4 mV specified by the manufacturer. If the analysis is pursued further and the absolute value of the noise level is measured, a more dramatic result is found. As mentioned in the previous section, the noise corrupting the output signal has a direct influence on the detectability threshold. A noisy signal forces the threshold to be raised and consequently reduces the dynamic range. One cannot expect to detect signals buried below the noise level. For the detector TH7805, this noise level is found to be:

20 mV for channel A
30 mV for channel B

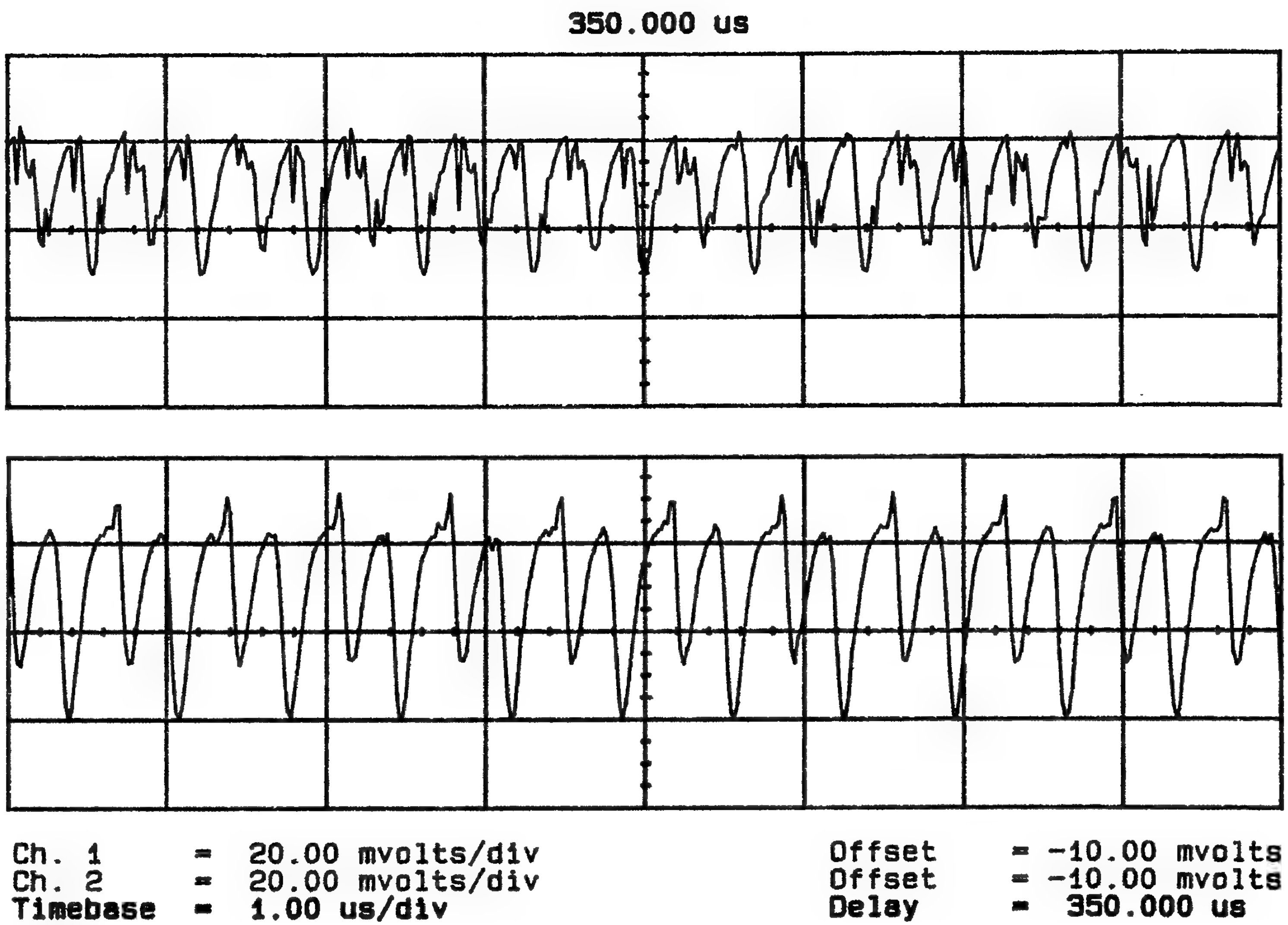

Fig. 8 Dark signal for both channels for an integration time of 1 ms.

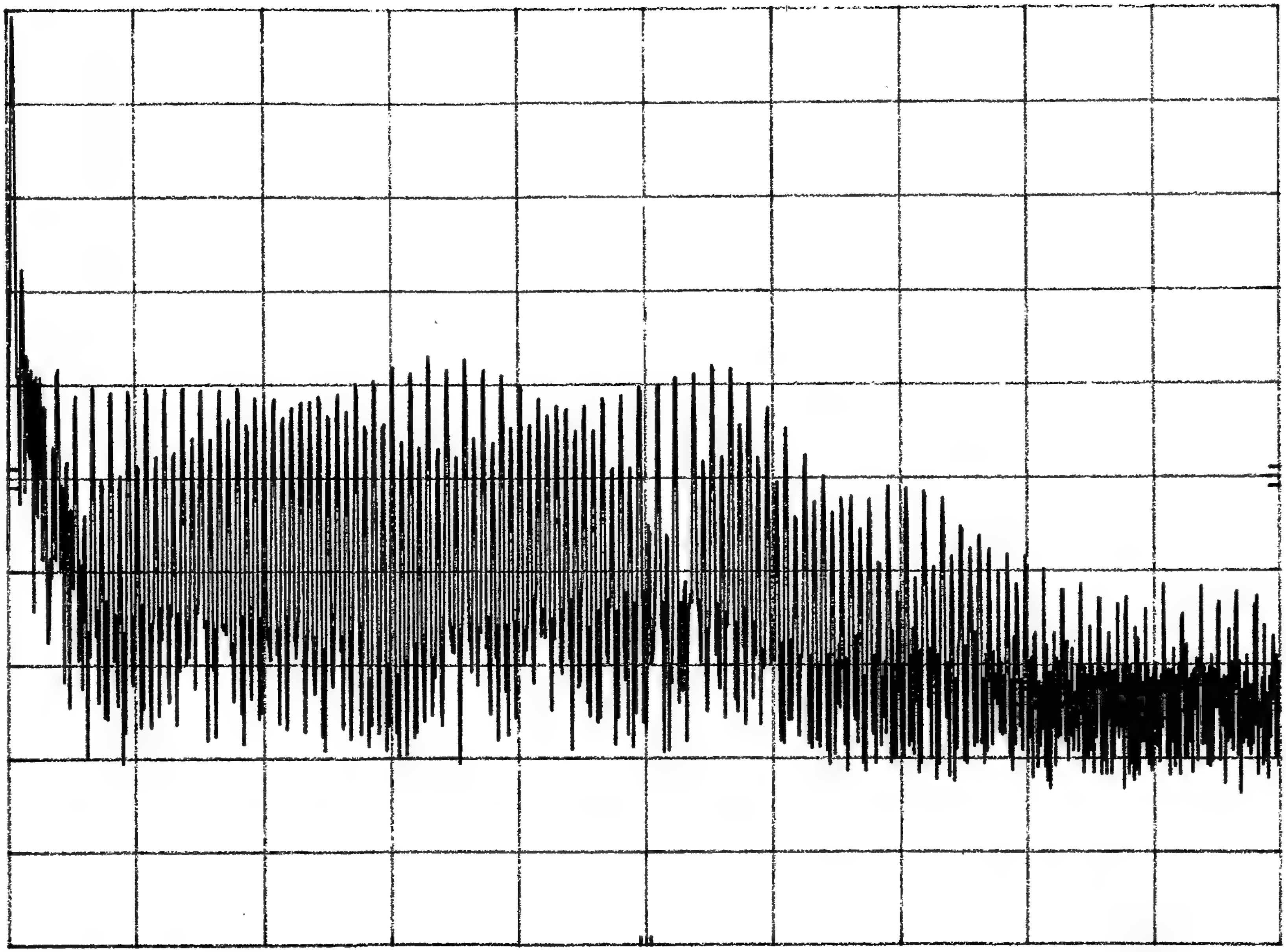

Fig. 9a Dark signal spectrum of channel A of TH7805

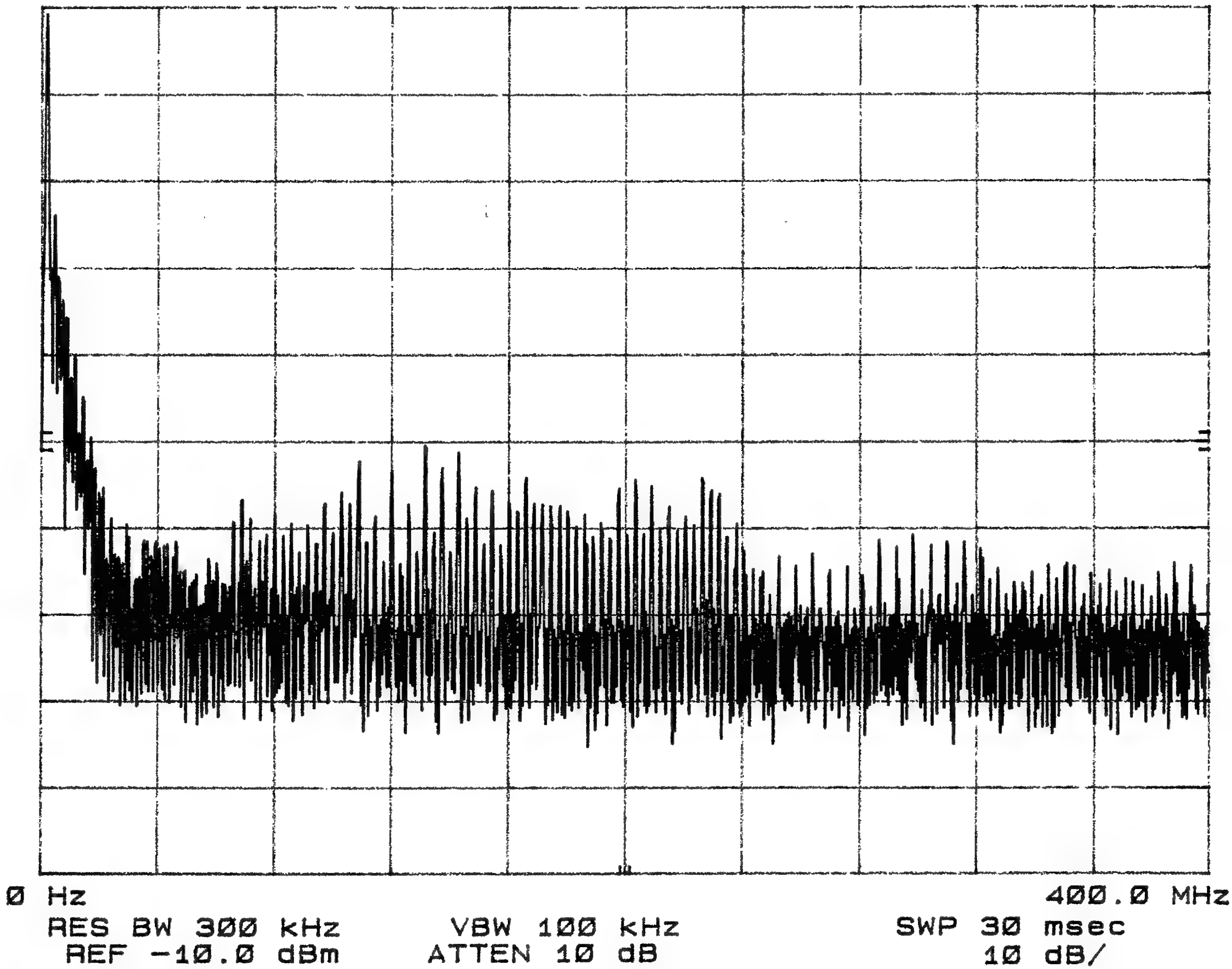

Fig. 9b Dark signal spectrum of channel B of TH7805

4.0 DETECTOR SENSITIVITY PROFILE

In linear array photodetectors, each element constitutes a separate measurement entity theoretically independent of the other elements of the detector. Nevertheless, it is desirable that all elements react identically and present identical output voltage when subjected to similar illumination levels. Unfortunately, few detectors will meet this criteria. It is then important to obtain a relation linking the output voltage of the different elements to the illumination intensity; to find the sensitivity profile of the detector.

To characterize the sensitivity profile of the detector, the following experiment is performed. The overall set-up remains similar to the one described in Chapter 2 (see Fig. 3). The laser light is focussed into a 3 μm wide vertical line onto one element of the detector. The laser intensity is kept constant and monitored from the calibrated detector. The use of a voltage regulator in the power line of the laser serves to reduce the possibility of fluctuations in the laser intensity which could be interpreted as variations of sensitivity.

The output voltage response, associated to the illuminated element, is then recorded as the average value of eight samples of the element's response. The same procedure can be repeated for every other elements. However, because of the prohibitive time required to scan all 2048 elements of the detector, the analysis is restricted to 30 selected elements per channel distributed along the detector. It is recommended that the elements chosen be analyzed using an interleaving scheme. For example, in the following experiments, the 30 chosen elements per channel were analyzed in 3 groups. The first group contained the 1,5,9,...,29 elements, the second group was composed of the 3,7,11,...27 elements and the third group had the 2,4,6,8,...30 elements of the 30 chosen. Proceeding in such a way permit to reduce even further the probability that a power drift of the main power system affects the interpretation of the readings.

The experiment was conducted for two different light intensities. In a first trial, the laser intensity was set to correspond to 30% of the detector's saturation level while in the second trial, it was set at 95% of the saturation level of the detector.

Tables 3a to 3d show the different results for each channel and illumination level. Columns 1 and 2 associate a time position to an element number. Column 3 shows the average value of eight consecutive output voltage readings for a given element and column 4, the standard deviation. Based on the maximum voltage value recorded for the particular trial, relative responses of the different elements were calculated (columns 5 and 6). Column 7 shows values of the relative response smoothed with a 3 point algorithm. Fig. 10 to 13 are based on the values presented in column 7 of the tables and show the sensitivity profiles of each channel of the detector under the two different intensity levels. Interpolation was used to approximate the response of the elements not analyzed.

Following this analysis, it can be seen that the sensitivity profile of the detector, although relatively linear, presents an upward trend for both channels as well as for both ends of the dynamic range, i.e. at 30% and 95% of the saturation point. A variation of ±10% in sensitivity level of the different elements is observed for each case analyzed. This figure contrasts with the manufacturer specifications which claim a sensitivity response non-uniformity of ±5% as reported in Table 1. The difference noted here is too severe to minimize its importance. In order to obtain an accurate representation of the true light distribution on the detector, a weighting factor must be associated to each element and included in the calculation of the actual voltage response. This correction could be performed by software manipulations on the results or by illuminating the detector array with an intensity distribution inversely proportional to the sensitivity profile of the array.

1	2	3	4	5	6	7
time (us)	element number	response (mv)	error (+/- mv)	relative response	error on relative	smoothing 3 points
11.51	3	276.11	1.07	78.80	.72	
24.80	41	267.42	1.07	76.32	.71	77.40
49.92	113	270.09	1.27	77.08	.77	76.03
75.08	185	261.67	1.68	74.68	.87	76.77
100.22	257	275.23	1.32	78.55	.79	75.06
125.38	329	252.07	2.37	71.94	1.05	75.63
149.75	399	267.64	1.98	76.39	.97	74.84
174.24	469	266.98	1.16	76.20	.73	76.81
200.08	543	272.78	2.20	77.85	1.04	77.44
225.20	615	274.22	1.98	78.26	.98	78.78
249.64	685	281.12	5.12	80.23	1.88	79.30
274.81	757	278.26	3.74	79.42	1.48	79.57
299.90	829	276.97	1.07	79.05	.72	79.06
322.97	895	275.84	1.21	78.73	.76	78.82
350.19	973	275.67	1.21	78.68	.76	79.54
374.67	1043	284.53	3.33	81.21	1.38	81.32
399.78	1115	294.63	1.65	84.09	.91	82.94
424.96	1187	292.62	1.32	83.52	.82	83.54
450.74	1261	290.88	3.91	83.02	1.55	83.62
475.23	1331	295.45	2.06	84.32	1.03	84.20
499.62	1403	298.70	1.38	85.25	.84	86.29
524.81	1475	312.89	1.62	89.30	.93	88.74
549.89	1545	321.22	1.43	91.68	.89	90.13
575.91	1621	313.33	1.93	89.43	1.02	91.47
600.89	1691	326.95	.91	93.31	.75	92.14
624.70	1761	328.27	2.12	93.69	1.10	93.71
649.76	1833	329.83	1.65	94.13	.97	93.36
674.99	1905	323.26	1.73	92.26	.98	95.46
700.04	1977	350.38	1.84	100.00	1.05	95.57
720.38	2033	330.91	1.73	94.44	.99	

Table 3a: Sensitivity response of channel A at 30% of saturation. Also shown are values of the relative responses smoothed at 3 points.

1	2	3	4	5	6	7
time (us)	element number	response (mv)	error (+/- mv)	relative response	error on relative	smoothing 3 points
12.22	5	750.52	3.82	78.51	0.91	
24.80	41	744.09	2.64	77.84	0.78	78.21
49.94	113	748.27	3.32	78.27	0.86	77.78
75.08	185	738.39	5.58	77.24	1.09	78.43
100.20	257	762.68	3.79	79.78	0.92	77.40
124.68	327	718.61	5.17	75.17	1.03	77.58
149.81	399	743.76	2.94	77.80	0.81	77.81
174.96	471	769.12	4.70	80.45	1.02	78.97
200.13	543	751.82	1.70	78.64	0.69	79.71
225.27	615	765.05	3.96	80.03	0.93	80.49
249.72	685	791.37	10.94	82.78	1.68	81.16
274.84	757	771.15	2.77	80.67	0.8	81.79
300.00	829	783.09	3.36	81.92	0.88	81.33
325.15	903	778.25	3.76	81.41	0.92	81.38
350.30	973	772.67	2.20	80.83	0.76	81.82
374.74	1043	795.66	2.72	83.23	0.83	83.71
399.89	1115	832.41	3.41	87.07	0.92	85.82
425.05	1187	833.15	4.48	87.15	1.04	86.65
450.21	1261	819.51	4.40	85.73	1.02	86.94
474.67	1331	840.77	4.26	87.95	1.02	87.22
499.78	1403	841.10	4.31	87.98	1.02	89.57
524.95	1475	886.98	3.71	92.78	0.99	91.45
550.12	1547	894.52	2.88	93.57	0.91	92.88
575.25	1619	882.25	1.46	92.29	0.75	94.20
599.75	1689	924.81	4.26	96.74	1.08	94.99
624.85	1761	917.19	6.60	95.94	1.31	96.32
649.97	1833	920.29	4.64	96.27	1.11	95.74
675.14	1905	908.36	4.23	95.02	1.06	97.10
700.41	1977	955.97	6.22	100.00	1.30	97.44
719.89	1033	930.28	5.33	97.31	1.19	

Table 3b: Sensitivity response of channel A at 95% of saturation. Also shown are values of the relative responses smoothed at 3 points.

1 time (us)	2 element number	3 response (mv)	4 error (+/- mv)	5 relative response	6 error on relative	7 smoothing 3 points
20.95	30	306.68	1.67	83.21	.73	
50.31	114	301.48	.57	81.80	.43	81.55
74.79	184	293.51	.76	79.64	.47	80.86
99.88	256	299.08	.73	81.15	.47	79.13
125.11	328	282.34	.85	76.61	.49	79.60
150.23	400	298.65	.40	81.03	.38	79.59
174.72	470	298.97	1.16	81.12	.59	81.35
199.80	542	301.79	.76	81.89	.48	82.68
225.06	614	313.41	.71	85.04	.48	83.43
250.15	686	307.25	1.50	83.37	.69	84.14
275.38	756	309.68	.76	84.03	.49	83.81
299.70	828	309.76	.93	84.05	.54	84.13
325.00	900	310.78	1.33	84.33	.64	83.89
350.08	972	306.94	1.50	83.28	.69	83.98
374.62	1044	310.75	1.07	84.32	.57	84.80
400.31	1118	319.94	.57	86.81	.45	85.75
424.95	1188	317.37	1.44	86.11	.68	86.12
450.07	1260	314.91	1.55	85.45	.71	86.57
475.29	1332	324.83	1.33	88.14	.66	87.61
500.21	1404	328.95	1.07	89.26	.59	89.13
524.90	1474	331.72	1.89	90.01	.82	90.08
550.04	1546	335.34	1.67	90.99	.76	91.08
575.21	1618	339.98	1.36	92.25	.68	92.75
600.84	1692	350.15	1.33	95.01	.68	94.22
624.83	1760	351.60	2.09	95.40	.89	95.98
650.02	1832	359.43	1.61	97.53	.76	97.64
675.18	1906	368.55	1.24	100.00	.67	98.04
700.07	1976	356.01	3.87	96.60	1.38	98.13
720.61	2036	360.39	5.12	97.79	1.72	

Table 3c: Sensitivity response of channel B at 30% of saturation. Also shown are values of the relative responses smoothed at 3 points.

1 time (us)	2 element number	3 response (mv)	4 error (+/- mv)	5 relative response	6 error on relative	7 smoothing 3 points
12.57	6	769.70	3.62	79.43	.73	-
25.15	42	778.41	2.80	80.33	.65	80.55
50.29	114	793.53	2.29	81.89	.60	81.75
74.72	184	804.58	6.25	83.03	1.02	82.30
99.86	256	794.21	2.43	81.96	.62	80.24
125.03	328	733.58	2.26	75.71	.57	78.20
132.70	350	745.28	1.61	76.91	.51	78.14
150.16	400	792.54	2.97	81.79	.67	79.47
175.34	472	772.22	2.52	79.69	.62	81.82
199.76	542	813.62	2.77	83.97	.66	82.05
224.91	614	799.15	1.55	82.47	.53	83.04
250.05	686	801.16	3.22	82.68	.70	82.59
275.21	756	800.48	2.40	82.61	.62	83.56
299.67	828	827.42	5.85	85.39	.98	84.36
324.82	900	824.45	2.77	85.09	.67	85.28
349.96	972	827.11	4.13	85.36	.81	85.37
375.12	1046	830.19	3.62	85.68	.76	86.91
400.25	1116	869.17	1.72	89.70	.58	87.55
424.68	1186	845.76	2.97	87.28	.70	88.12
449.86	1258	846.53	4.18	87.36	.82	87.77
474.99	1330	859.22	5.06	88.67	.92	88.88
500.14	1402	877.90	2.15	90.60	.63	90.49
525.30	1476	893.45	2.97	92.21	.72	92.66
549.76	1546	922.05	3.25	95.16	.76	93.39
574.90	1618	899.30	2.91	92.81	.71	95.59
600.04	1690	957.50	3.93	98.82	.85	96.87
625.20	1762	959.05	2.91	98.98	.74	99.15
649.65	1832	965.74	3.08	99.67	.76	99.09
674.82	1904	955.74	3.87	98.63	.84	99.43
699.93	1976	968.97	4.32	100.00	.89	99.14
720.22	2034	957.27	5.51	98.79	1.01	

Table 3d: Sensitivity response of channel B at 95% of saturation. Also shown are values of the relative responses smoothed at 3 points.

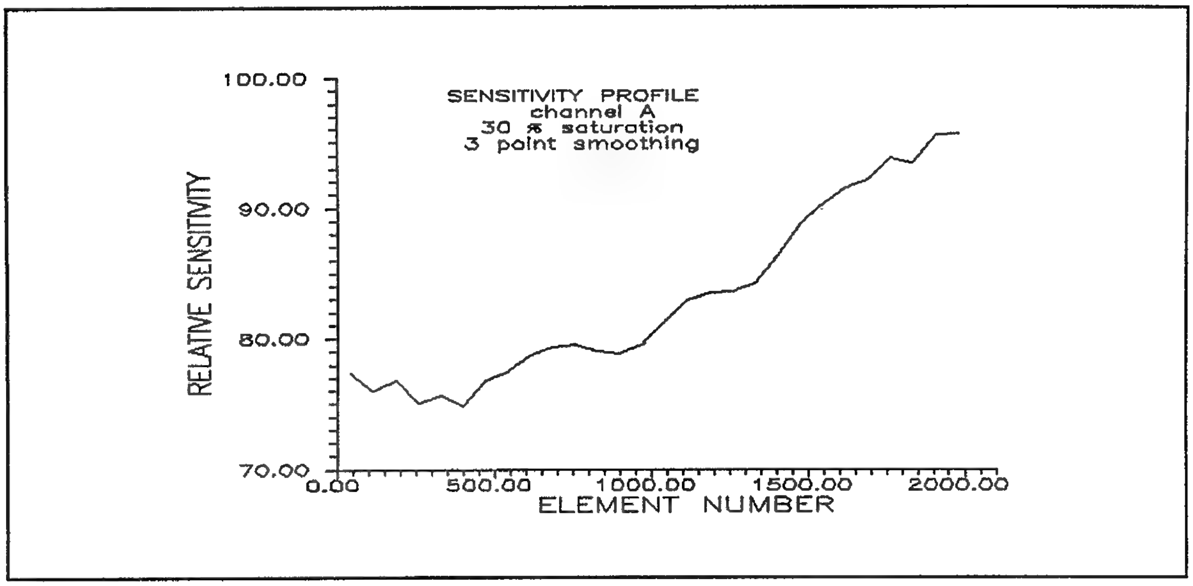

Fig. 10 Sensitivity profile of channel A at 30% of saturation. (Reference: Table 3a).

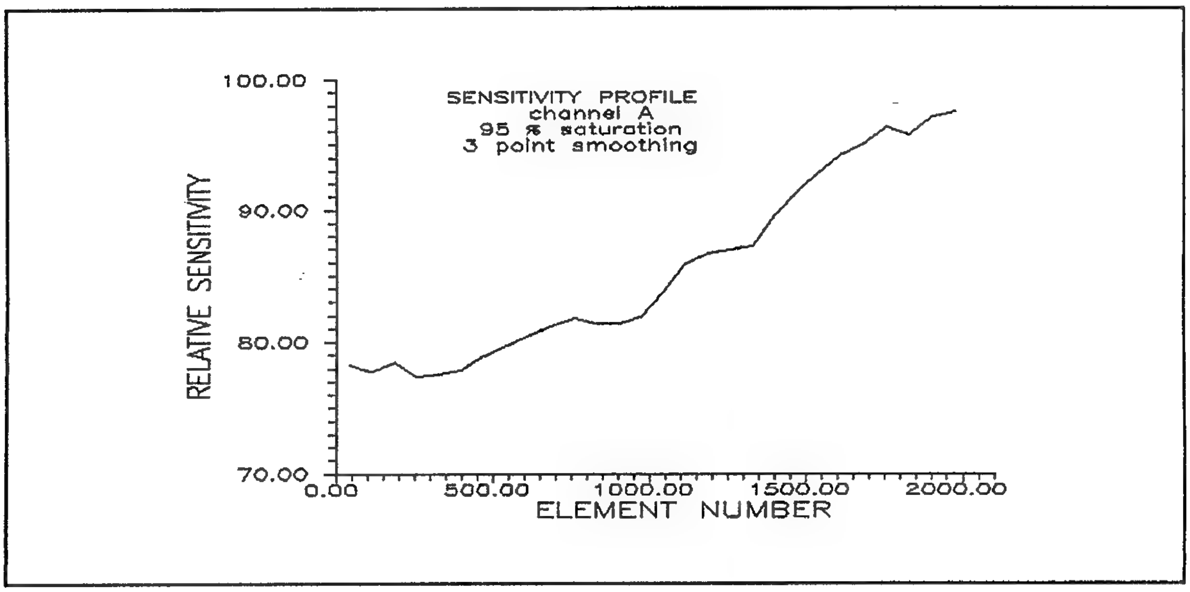

Fig. 11 Sensitivity profile of channel A at 95% of saturation. (Reference: Table 3b).

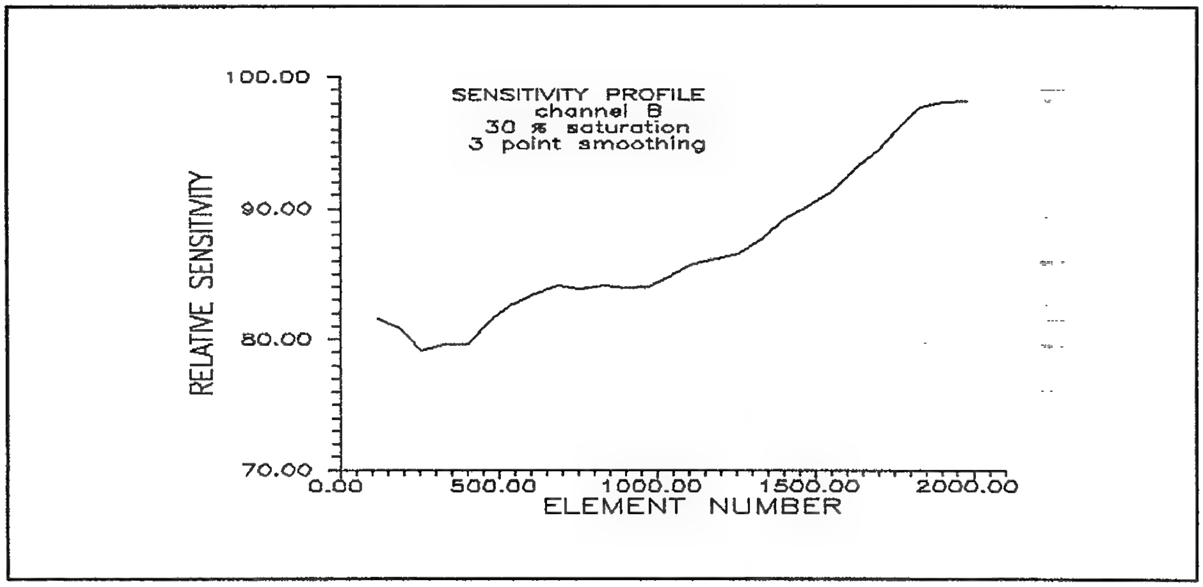

Fig 12 Sensitivity profile of channel B at 30% of saturation. (Reference: Table 3c).

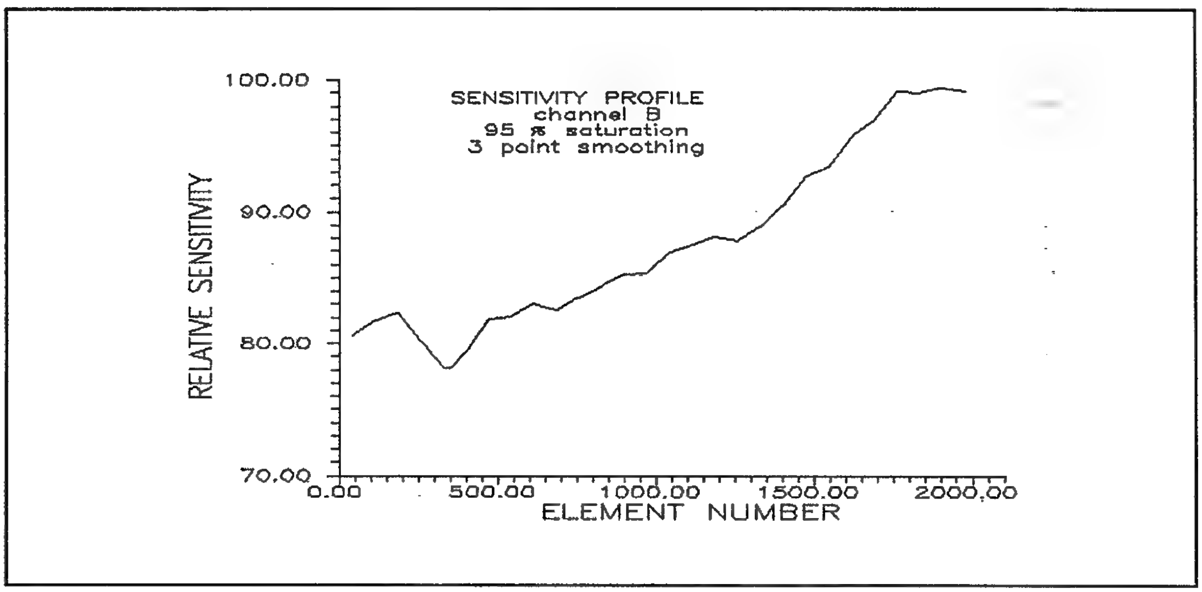

Fig. 13 Sensitivity profile of channel B at 95% of saturation. (Reference: Table 3d).

5.0 ELEMENT SENSITIVITY PROFILE

In many applications, the ability to clearly identify the details of the optical pattern, i.e. to precisely define the spatial structure of the image, is important. High resolution detectors such as linear array detectors are, in these instances, suitable candidates. It is advisable to measure the resolution performance of the detector to ensure that the requirements of the overall system can be met.

In this chapter, a procedure is given to evaluate the resolution profile of a linear array detector. The profile is shown as a relation between the voltage response of the detector's elements and the horizontal position of the incident focussed beam. The procedure consists in slowly translating the detector across the focussed laser beam so that each element be successively illuminated. The detector is translated in increments of 1.3 μm. This allows the profile to be sampled approximately ten times per element. Moreover, since the intensity of the incident light, and consequently the output voltage, may modify the sensitivity profile of the elements, it is advisable to perform the experiment at different light intensities. For the purpose of this study, two tests were performed. In the first one, the light intensity was set at 30% of the saturation point of the detector and in the second trial at 95% of the saturation point.

Because of the prohibitive amount of time required for an evaluation of the profile of each element, only four regions of six elements each over the length of the array were tested at both intensity levels. Table 4 indicates the elements that were analyzed for both intensity levels.

Fig. 14 to 21 show the sensitivity profile of each group of elements. The graphs present the relation between the normalized voltage response of the element versus the position of the light beam on the detector. Normalization of the output voltages is relative to the output voltage of the most sensitive element of the detector. As seen, the profiles take the form of a bell shape. As the light beam approaches the centre of an element, maximum energy is focussed on the element, resulting in a higher voltage response sampled. This region of high sensitivity spans over approximately 10 μm for each element. When the laser beam moves outside the area, the sensitivity quickly drops off. At a position 13 μm from the centre of an element the voltage response is reduced to the noise level, approximately 10 dB lower. In between each area of maximum sensitivity, characterizing the element themselves, there exists a transition area of approximately 5 μm wide where the sensitivity is reduced. This area is associated with the interelement dead space. These dead space regions are inherent with linear array detectors and result from manufacturing constraints. The sensitivity of the detector for a light beam falling directly in between two elements will generate approximately 55% of the maximum response.

	30%	95%
elements	253 to 258	117 to 122
elements	547 to 552	583 to 588
elements	1407 to 1412	1131 to 1136
elements	1974 to 1984	1397 to 1402

Table 4 Number of the elements tested for sensitivity profile at 30% and 95% of the saturation intensity level.

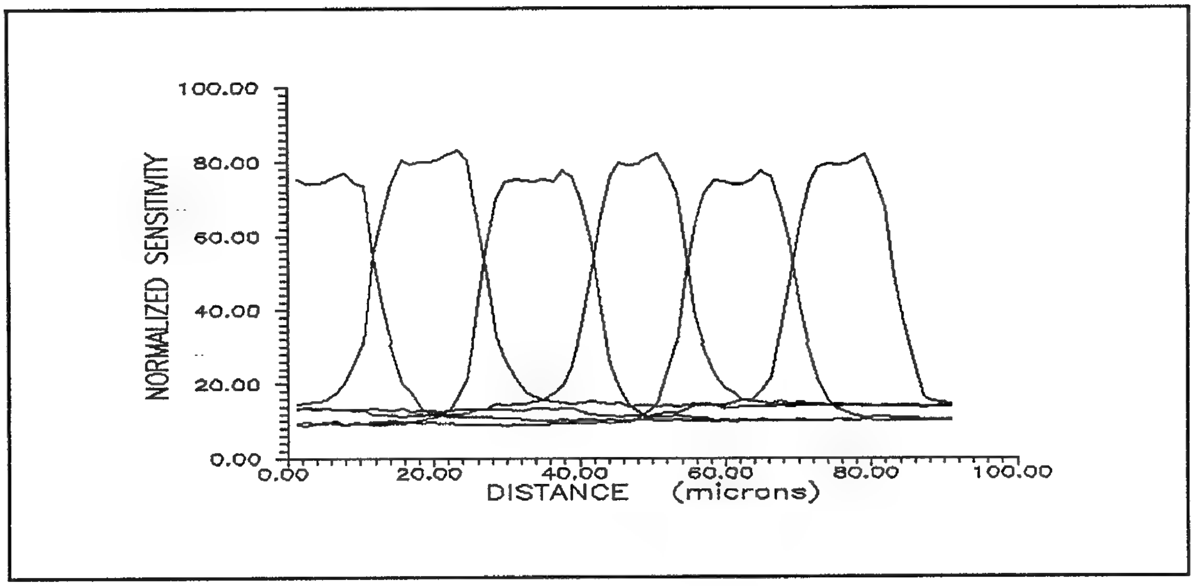

Fig. 14 Sensitivity profile of elements 253 to 258 for an illumination level of 30% of the saturation level and for an integration time of 1 ms.

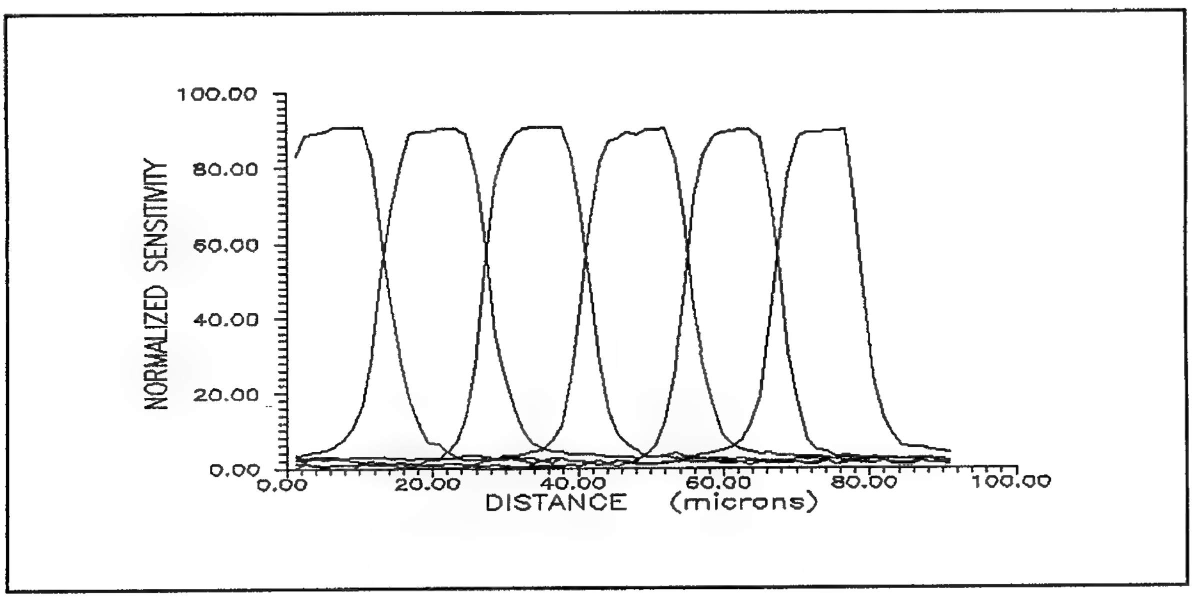

Fig. 15 Sensitivity profile of elements 547 to 552 for an illumination level of 30% of the saturation level and for an integration time of 1ms.

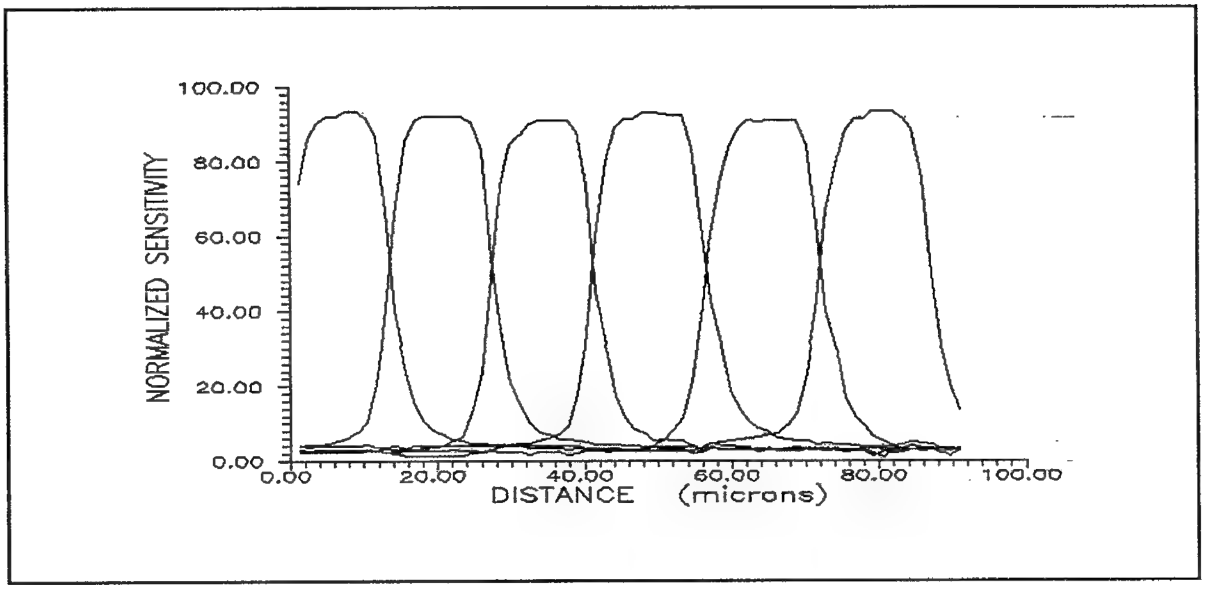

Fig. 16 Sensitivity profile of elements 1407 to 1412 for an illumination level of 30% of the saturation level and for an integration time of 1ms.

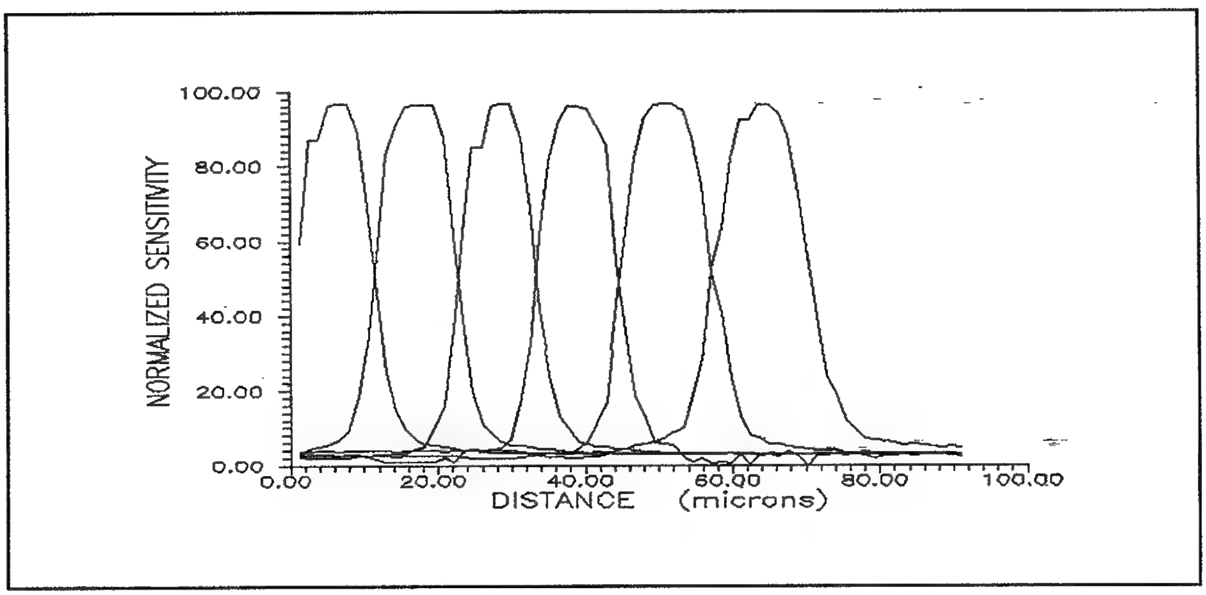

Fig. 17 Sensitivity profile of elements 1979 to 1984 for an illumination level of 30% of the saturation level and for an integration level of 1ms.

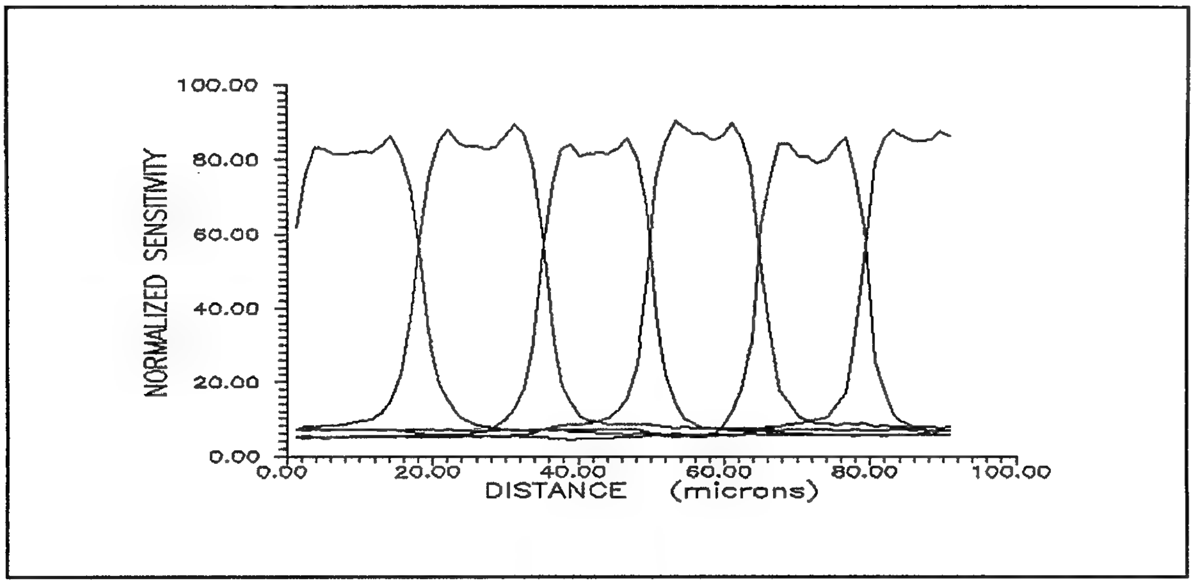

Fig. 18 Sensitivity profile of elements 117 to 122 for an illumination level of 95% of the saturation level and for an integration time of 1ms.

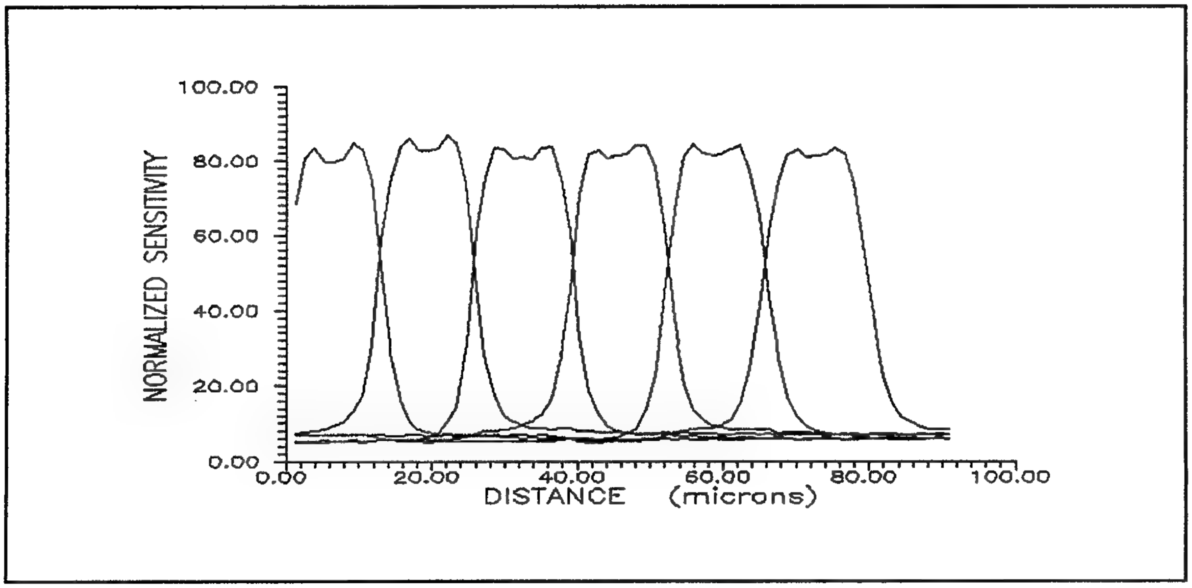

Fig. 19 Sensitivity profile of elements 583 to 588 for an illumination level of 95% of the saturation level and for an integration time of 1ms.

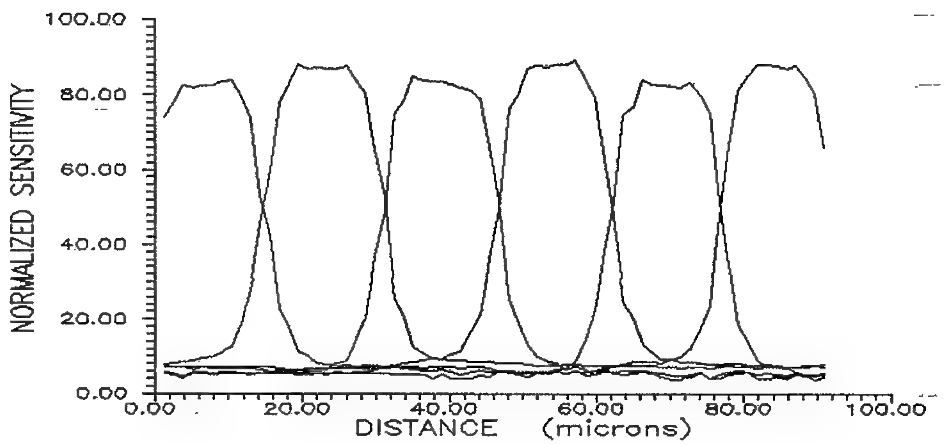

Fig. 20 Sensitivity profile of elements 1131 to 1136 for an illumination level of 95% of the saturation level and for an integration time of 1ms.

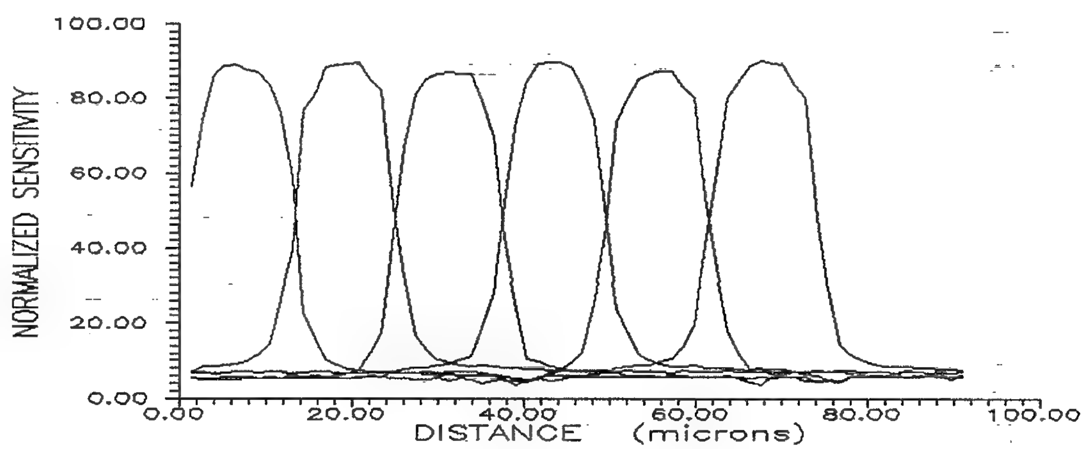

Fig. 21 Sensitivity profile of elements 1397 to 1402 for an illumination level of 95% of the saturation level and for an integration time of 1ms.

6.0 DYNAMIC RANGE

Another very important aspect to evaluate when choosing a detector is the dynamic range of the detector, i.e. its capability to respond linearly to various levels of light intensity. The lower limit of the dynamic range is identified as being the amount of energy (or power) required in the incident laser beam to produce a response signal from an element just higher than the dark signal (see Fig. 6a and 6b). The upper limit corresponds to the energy needed to saturate the element (see Fig. 7a and 7b). Once the range has been established, when the minimum and maximum incident energy levels have been found, it is useful to evaluate the linearity of the region in between those extremes.

To perform this evaluation, the following procedure is used. The detector is kept stationary, with one of the elements illuminated by the laser beam. The spherical lens is used to concentrate the total energy of the beam onto the element. The intensity of the incident beam is varied using the two stages of attenuation (see Fig. 3 and 4). The limits of the dynamic range are measured by removing the detector TH7805, once the minimum and maximum levels have been observed on the oscilloscope, and replacing it with the calibrated detector. It was also found that similar results could be obtained if the readings were taken from the calibrated detector positioned immediately following the two stages of attenuation.

The analysis of the dynamic range linearity of the TH7805 is evaluated for one element per channel under three (3) different times of integration (0.1 ms, 1.0 ms, 10 ms). Figs. 22 and 23 show, for each of the 6 experiments, the linearity of the response of the chosen elements. In every test performed, it is observed that the output signal voltage is proportional to the incident laser energy. Table 5 presents a detailed description of the results of the experiment. The dynamic range for both channels and three integration times averages around 21 dB. This value contrasts with the 37.8 dB claimed by the manufacturer. It is to be noted however that the two values have not been calculated with the same parameters. In this experiment, the dynamic range is evaluated as a ratio of laser powers while the manufacturer uses a ratio of the voltage response at saturation to the voltage response of the dark signal. When the method proposed by the manufacturer is used to test the dynamic range of this detector, a value of only 17 dB is found.

It is worth noting that the saturation level of 1.0 V observed during the experiments (Table 5) could be increased to 4.0 V if the illumination system is modified. When a flashlight is shined directly on the detector, instead of the collimated laser beam, the saturation level raises to 4.0 V. It was however impossible to obtain any response value between 1.0 V and 4.0 V. Although 4.0 V is the value specified by the manufacturer as the saturation level, it can not be considered valid for the purpose of performance evaluation since a flashlight can not be used as an illumination system in real applications.

From the analysis performed here, it is observed that the saturation exposure for the Thomson CSF TH7805 is 28.0 $\mu J/cm^2$. This value is based on the

laser power required to saturate an element of 10 μm by 13 μm for different integration times. The manufacturer claimed 0.38 $\mu J/cm^2$ for the saturation exposure.

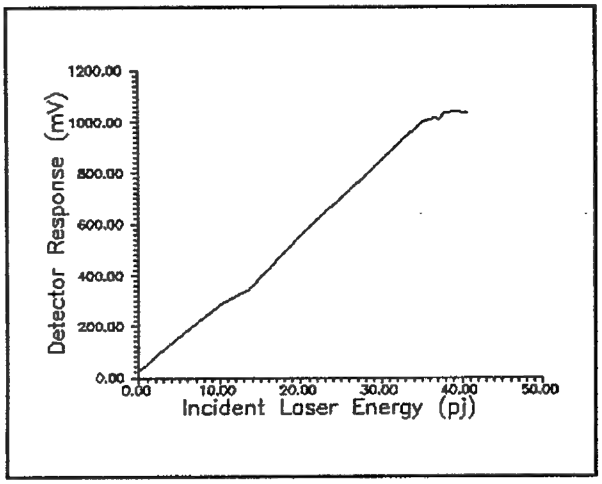

Fig. 22 a)

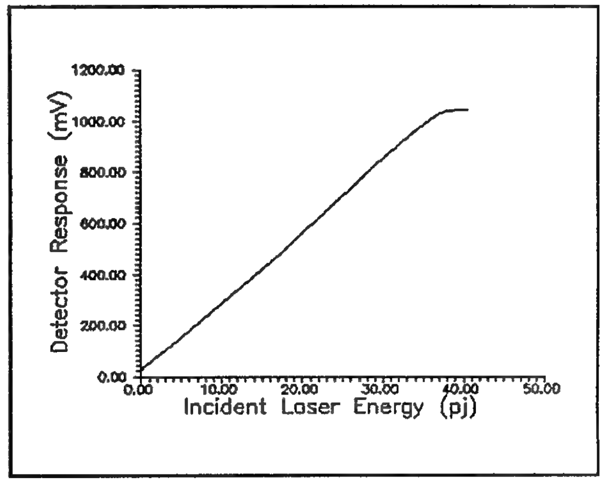

Fig. 22 b)

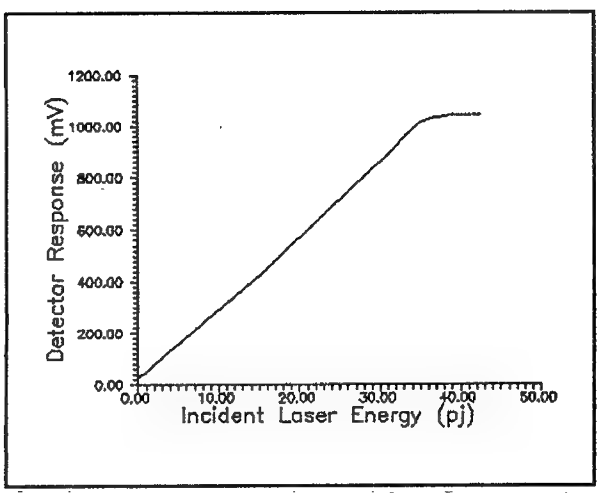

Fig. 22 c)

DYNAMIC RANGE - CHANNEL A

Each Figure corresponds to a different integration time.
Fig. 22a = 100μs
Fig. 22b = 1ms
Fig. 22c = 10ms

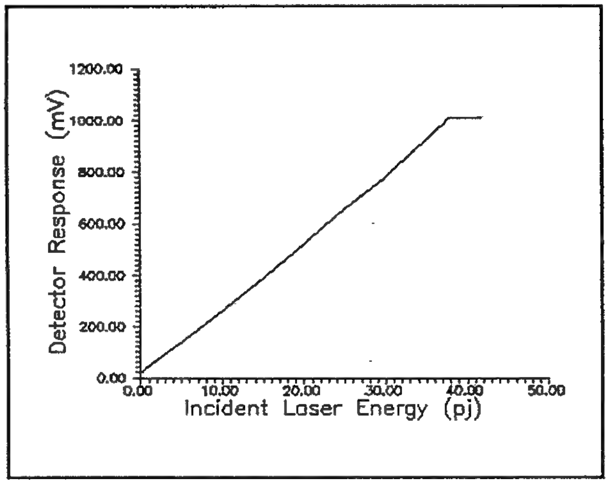

Fig. 23 a)

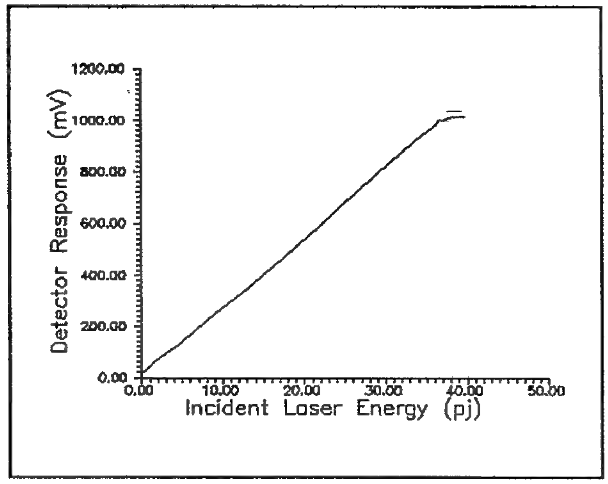

Fig. 23 b)

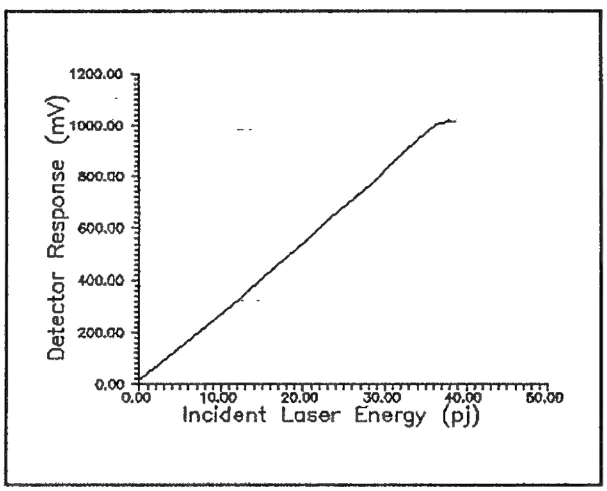

Fig. 23 c)

DYNAMIC RANGE - CHANNEL B

Each Figure corresponds to a different integration time.
Fig. 23a = 100μs
Fig. 23b = 1ms
Fig. 23c = 10ms

CHANNEL	ELEMENT NUMBER	INTEGRATION TIME (msec)	DARK SIGNAL (mV)	MINIMUM LASER POWER DETECTABLE (nW)	RESPONSE TO MINIMUM LASER POWER (mV)	MAXIMUM LASER POWER SATURATION (nW)	RESPONSE TO SATURATION POWER (V)	DYNAMIC RANGE $10 \cdot \log\frac{\text{MAX POWER}}{\text{MIN POWER}}$ (dB)
A	979	0.1	29.0	3.2	35.3	378	1.03	21.0
A	979	1	29.0	0.32	35.0	37.8	1.04	20.7
A	977	10	29.0	0.03	35.6	3.78	1.04	21.0
B	984	0.1	20.0	2.5	26.7	378	1.01	21.7
B	974	1	20.0	0.30	26.5	37.8	1.01	21.0
B	982	10	20.0	0.03	26.7	3.78	1.02	20.6

Table 5 Detailed description of the results obtained for the measurement of the dynamic range of the Thomson CSF TH7805

7.0 CONCLUSION

In this report, experimental procedures to evaluate the performance of linear array photodetectors are given. The procedures describe focus on the evaluation of four different aspects of the detector. The output signal is first evaluated in terms of its structure (shape and timing of pulses) and of the noise induced by the detector itself. Then follows two tests used for the evaluation of the sensitivity profile. The first serves to verify the uniformity of the response of the different elements of the detector under a constant illumination level. The second test concentrates on individual elements and analyzes their resolution performance, their ability to precisely identify details of the image spatial structure. Finally, the last test describes an evaluation procedure for the dynamic range of the detector.

Each one of those testing procedures is applied to a linear image sensor TH7805 and its driver module THX1061 from Thomson CSF. Results of the tests are also included in the report. Table 6 summarizes the results obtained and compares them to the specifications given by the manufacturer.

It is observed that this device TH7805 tested in conjunction with the THX1061 driver board does not respond according to manufacturer's specifications. A major problem comes from the leakage of the system clock in the output signal. The noise level is much higher then specified by the manufacturer. Consequently, the dynamic range is drastically lowered. The linear array TH7805 would probably benefit from the use of the improved driver module TH7932, now available from Thomson CSF, which is claimed to have a lower clock noise.

THOMPSON CSF TH7805

	Manufacturer Specifications	Test Results
Number of photodiodes	2048	2048
Size of elements	$13\mu m$ X $13\mu m$	13 μm horizontally
Size of sensitive portion	$10\mu m$ X $13\mu m$	10 μm horizontally
Output data rate (1ms integration time)	5 MHz	2.9 MHz
Average dark signal	0.5 mV	0.4 mV
RMS noise in darkness	0.4 mV	5 mV channel A 13 mv channel B
Maximum amplitude of noise	--	20 mV channel A 30 mV channel B
Interelement isolation	--	10 dB
Signal response non-uniformity	±5%	±10%
Difference between responses of channel A and B	5%	--
Saturation of output voltage	1.7V to 4.5V	1.0V
Saturation exposure	$0.38\mu J/cm^2$	$29.1\mu J/cm^2$
Dynamic range	37.78 dB (relative to) (RMS noise)	21 dB (relative to) (maximum amplitude) (of noise)

Table 6 Comparison of experimental results and manufacturer specifications for the Thomson CSF TH7805 linear array detector and Driver Module THX1061.

ANNEX A

SOFTWARE USED FOR THE EXPERIMENTATION

In Annex A, the software used for the automation of the different experiments is presented. Two programs were developopped.

"Peakval" determines the timing position and the value of the maximum amplitude point of the signal in channel A or B of the oscilloscope HP54100A/D. The program is used for the evaluation of the signal characteristics, detector sensitivity profile and dynamic range.

"Profile" divides, in the time domain, the output signal of the detector in timing bins the size of an element's sample. In each bin, the maximum value is recorded and associated with the response of the particular element. The program is used for the evaluation of the element sensitivity profile.

PEAKVAL

```
CLEAR    ,57996!
IBINIT1 = 57996!
IBINIT2 = IBINIT1 + 3
BLOAD "BIB.M",IBINIT1
CALL IBINIT1(IBFIND,IBSTOP,IBTRG,IBCLR,IBPCT,IBSIC,IBLOC,
          IBPPC,IBBNA,IBONL,IBRSC,IBSRE,IBRSV,IBPAD,
          IBSAD,IBIST,IBDMA,IBEOS,IBTMO,IBEOT)
CALL IBINIT2(IBGTS,IBCAC,IBWAIT,IBPOKE,IBWRTF,IBWRTA,IBWRT,
          IBCMDA,IBCMD,IBRDF,IBRDA,IBRD,IBRPP,IBRSP,
          IBDIAG,IBXTRC,IBSTA%,IBERR%,IBCNT%)
REM The following declarations may optionally be included in the user
    application program.  They provide appropriate mnemonics by which
REM to reference commonly used values.  Some mnemonics (GET%, ERR%,
 END%, ATN%) are preceded by "B" in order to distinguish them from
    BASICA keywords.
REM
REM GPIB Commands
REM
UNL% = &H3F       ' GPIB unlisten command
UNT% = &H5F       ' GPIB untalk command
GTL% = &H1        ' GPIB go to local
SDC% = &H4        ' GPIB selected device clear
PPC% = &H5        ' GPIB parallel poll configure
BGET% = &H8       ' GPIB group execute trigger
TCT% = &H9        ' GPIB take control
LLO% = &H11       ' GPIB local lock out
DCL% = &H14       ' GPIB device clear
PPU% = &H15       ' GPIB ppoll unconfigure
SPE% = &H18       ' GPIB serial poll enable
SPD% = &H19       ' GPIB serial poll disable
PPE% = &H60       ' GPIB parallel poll enable
PPD% = &H70       ' GPIB parallel poll disable
REM
REM GPIB status bit vector
REM global variable IBSTA% and wait mask
REM
BERR% = &H8000   ' Error detected
TIMO% = &H4000   ' Timeout
BEND% = &H2000   ' EOI or EOS detected
SRQI% = &H1000   ' SRQ detected by CIC
RQS% = &H800     ' Device needs service
CMPL% = &H100    ' I/O completed
LOK% = &H80      ' Local lockout state
REM% = &H40      ' Remote state
CIC% = &H20      ' Controller-In-Charge
BATN% = &H10     ' Attention asserted
```

```
TACS% = &H8       ' Talker active
LACS% = &H4       ' Listener active
DTAS% = &H2       ' Device trigger state
DCAS% = &H1       ' Device clear state
REM
REM Error messages returned in global variable IBERR%
EDVR% =  0        ' DOS error
ECIC% =  1        ' Not CIC (or lost CIC during command)
ENOL% =  2        ' Write detected no listeners
EADR% =  3        ' Board not addressed correctly
EARG% =  4        ' Bad argument to function call
ESAC% =  5        ' Function requires board to be SAC
EABO% =  6        ' Asynchronous operation was aborted
ENOA% =  7        ' Non-existent board
ESYN% = 10        ' New I/O attempted with old I/O in progress
ECAP% = 11        ' No capability for intended operation
EFIL% = 12        ' File system operation error
EBUS% = 14        ' Bus error
ESTB% = 15        ' Serial poll status byte lost
ESRQ% = 16        ' SRQ remains asserted
REM
REM EOS mode bits
BIN% = &H1000     ' Eight bit compare
XEOS% = &H800     ' Send EOI with EOS byte
REOS% = &H400     ' Terminate read on EOS
REM
REM Timeout values and meanings
REM
TNONE% =   0      ' Infinite timeout (disabled)
T10US% =   1      ' Timeout of 10 us (ideal)
T30US% =   2      ' Timeout of 30 us (ideal)
T100US% =  3      ' Timeout of 100 us (ideal)
T300US% =  4      ' Timeout of 300 us (ideal)
T1MS% =    5      ' Timeout of 1 ms (ideal)
T3MS% =    6      ' Timeout of 3 ms (ideal)
T10MS% =   7      ' Timeout of 10 ms (ideal)
T30MS% =   8      ' Timeout of 30 ms (ideal)
T100MS% =  9      ' Timeout of 100 ms (ideal)
T300MS% = 10      ' Timeout of 300 ms (ideal)
T1S% =    11      ' Timeout of 1 s (ideal)
T3S% =    12      ' Timeout of 3 s (ideal)
T10S% =   13      ' Timeout of 10 s (ideal)
T30S% =   14      ' Timeout of 30 s (ideal)
T100S% =  15      ' Timeout of 100 s (ideal)
T300S% =  16      ' Timeout of 300 s (ideal)
T1000S% = 17      ' Timeout of 1000 s (maximum)
REM
REM Miscellaneous
REM
S% = &H8
LF% = &HA
REM
```

```
92      REM Application program variables passed to
93      REM GPIB functions
94      REM
95      CMD$ = SPACE$(10)        ' command buffer
96      RD$ = SPACE$(255)        ' read buffer
97      WRT$ = SPACE$(255)       ' write buffer
98      BDNAME$ = SPACE$(7)      ' board/device name
99      FILE$ = SPACE$(50)       ' file name



100 REM                     "PROGRAM PEAKVAL"
120 REM
140 REM  "This program may be used to determine the amplitude of the"
160 REM  "most negative peak on the trace of the oscilloscope HP 54100A/D"
180 REM
200 REM  "You must enter after being requested:"
220 REM           a. Which file of A:\GAIN\ are the results going to be stored
240 REM           b. Which channel you want to analyze;
260 REM           c. The zero voltage mark, in terms of scope unit;
280 REM           d. The volt/division being used;
300 REM           e. The laser power used on the detector array.

320 REM  "Note: Clarification on point c. The scope digitizes the vertical scale
           in 128 units, with the lowest voltage shown being 0 and the highest
         127. Point C ask that you express the zero voltage in terms of scope
340 REM   unit e.g. if the lowest voltage on the scope is -100V and that you work
          at 10 V/division, the 0 unit is -100V and the 127th unit is -20V
          (because there are 8 divisions on the scope) The zero voltage mark is
360 REM   then 160 scope units. You would then answer question c by 160.
380 REM
400 REM   The program find the minimum value of the first 256 digitized points
          (Which is the first half of the time scale since the program set the
          digitizing number of points to 256).
420 REM   Then the scope unit associated to this minimum value is substracted
          to the zero mark unit of question c. The result is converted in volts
          according to question d. This same operation is performed 5 times.
440 REM   The output shows the result of the 5 operations and some statisitcs
          on them:
460 REM              - Average value of the time after trigger of the peak
480 REM              - Average value of the peak
500 REM              - Standard deviation of the measurements
520 REM              - Minimum peak value measured
540 REM              - Maximum peak value measured
560 REM
580 REM
600 REM   Note that this program is written for the case that you use the
          split screen function of the scope. If you do not use this function
          you must modify the equation for VDIV to read VDIV=(8*VOLTDIV)/128
620 REM
```

```
640 REM   The result are printed on printer and saved on disk drive A in
          directory "gain" and filename as you gave in question a.
660 REM
680 REM
700 REM
720 REM  "Define Vector space"
740     ADNAME$ = SPACE$(7)                         'GPIB board name
760     DEVNAME$ = SPACE$(7)                        'device name
780     WAVE$=SPACE$(255)                           'vector for digitized values
800     XIT$=SPACE$(128) : XI$=SPACE$(128)          'transient variables
820     XOT$=SPACE$(128) : XO$=SPACE$(128)          'transient variables
840     Y$=SPACE$(128)   : Z$=SPACE$(128)           'transient variables
860     DIM VALUE(150)                'will contain values last digitized wavefor
880     DIM YMEM(500)                               'memory for the minimum values
900 REM
920 REM  "Initialize some variables
940     COUNT = 0  'counter for the number of readings of the waveform to take
960     SUMT  = 0  'Holds the summation of the scope unit value of the peak
980     TIMT  = 0  'Holds the summation of the time of the peak
1000    VARI  = 0  'Is the variance of the peak measurements
1020    STDDEV= 0  'Is the standard deviation of the peak measurements
1040    NUMPTS=128 'Number of points read from the scope
1060 REM
1080 REM
1100 REM                        "INITIALIZATION"
1120 REM
1140 REM
1160 REM   "Questions to define different parameters
1180      PRINT "Which file of DRIVE A are the results going" : INPUT FILENA$
1200      PRINT "Which channel do you want to test 1 or 2    " : INPUT KCHAN
1220      PRINT "enter dark signal in that channel           " : INPUT DARK
1240      PRINT "enter millivolt/division being used          " : INPUT VOLTDIV
1260      PRINT "WHAT WAS THE LASER INTENSITY RECORDED" : INPUT LASER
1280     VDIV = (4*VOLTDIV)/128
1300 REM
1320 REM  "Open file to save the data
1340     FILE$ = "a:\gain\" + FILENA$ +".dat"
1360     OPEN FILE$ FOR OUTPUT AS #1
1380 REM
1400     LPRINT " " : LPRINT " " : LPRINT " " : LPRINT " "
1420     LPRINT "EXPERIMENT NAME :  ";FILENA$
1440 REM
1460 REM
1480 REM   "Initialize gpib adapter and devices
1500      ADNAME$="GPIB0"        : CALL IBFIND(ADNAME$,GPIB0%)
1520      DEVNAME$="SCOPE"       : CALL IBFIND(DEVNAME$,SCOPE%)
1540 REM  "set gpib0 controller in charge
1560      CALL IBSIC(GPIB0%)
1580      V%=1 : CALL IBSRE(GPIB0%,V%)
1600 REM
1620 REM  "set the scope parameters for the acquisition process"
1640      WRT$="acq;type2;count8;comp100;poin256" : CALL IBWRT(SCOPE%,WRT$)
```

```
1660 REM
1680 REM  "Obtain from the scope the values of the time and voltage increments

1700      WRT$ = "dig1":CALL IBWRT(SCOPE%,WRT$)
1720      WRT$ = "head0 wav src1 form2 data?" : CALL IBWRT(SCOPE%,WRT$)
1740      WRT$ = "head1 xinc?" : CALL IBWRT(SCOPE%,WRT$) : CALL IBRD(SCOPE%,XI$)
1760      WRT$ = "head1 xor?"  : CALL IBWRT(SCOPE%,WRT$) : CALL IBRD(SCOPE%,XO$)
1780      XIT$ = MID$(XI$,7,12) : XI = VAL(XIT$)
1800      XOT$ = MID$(XO$,7,12) : XO = VAL(XOT$)

1820 REM
1840 REM                        "DATA ACQUISITION"
1860 REM
1880 REM  "Start of a loop to average a number of reading set by "COUNT"
1900 REM  "The loop goes from 1940 to 2940
1920 REM
1940 REM  "Initialize the vector receiving values of the digitized waveform
1960      FOR I = 1 TO NUMPTS
1980       VALUE(I)=0
2000      NEXT I
2020 REM
2040 REM  "Set different variables
2060      SUMV=0
2080      COUNT=COUNT+1
2100      YFMIN=128
2120 REM
2140 REM  "digitize the waveform from the specified channel"
2160       IF KCHAN=2 THEN 2240
2180          WRT$="dig1": CALL IBWRT(SCOPE%,WRT$)
2200          WRT$="head0 wave src1 form2 data?" : CALL IBWRT(SCOPE%,WRT$)
2220       GOTO 2300
2240          WRT$="dig2": CALL IBWRT(SCOPE%,WRT$)
2260          WRT$="head0 wave src2 form2 data?" : CALL IBWRT(SCOPE%,WRT$)
2280 REM  "Read this digitized waveform and store the values in Value(k)
2300       CALL IBRD(SCOPE%,WAVE$)
2320        FOR K=3 TO NUMPTS-1
2340         Y$=MID$(WAVE$,2*K-1,1) : Y%=ASC(Y$)
2360         Z$=MID$(WAVE$,2*K,1)   : Z%=ASC(Z$)
2380         YZ= Y% + (Z%/256)
2400         VALUE(K-2)= YZ
2420        NEXT K
2440 REM
2460 REM "Location of the peak value and its position in scope unit
2480      FOR I=1 TO 125
2500       IF YFMIN<VALUE(I) THEN 2560
2520        YFMIN=VALUE(I)
2540        YPOS = I
2560      NEXT I
2580 REM
2600 REM "Transformation of the scope unit in millivolt and microsecond unit
2620      TMPS = (XO + (YPOS*XI)) * 1000000!
2640      YVAL = (DARK - YFMIN) * VDIV
```

```
2660      YMEM(COUNT)=YVAL
2680      SUMT=SUMT+YVAL
2700      TIMT = TIMT + TMPS
2720 REM
2740 REM "Print and save preliminary results
2760    LPRINT USING"  Peak is at ###.### usec with value of ###.###";TMPS,YVAL
2780    PRINT  USING"  Peak is at ###.### usec with value of ###.###";TMPS,YVAL
2800      WRITE #1,TMPS,YVAL
2820 REM
2840 REM "Once the number of averages completed
2860 REM "Calculate -mean volt value of the peak (MEAN)
2880 REM            -mean time value of the peak (TIMT)
2900 REM            -Minimum and maximum recorded values of the peak
2920 REM            -Variance and Standard deviation of the measurements
2940      IF COUNT<5 THEN 1940
2960       MEAN=SUMT/COUNT
2980       TIMT=TIMT/COUNT
3000       MINI=999 : MAXI=0
3020       FOR J = 1 TO COUNT
3040        VARI = VARI + ((YMEM(J) - MEAN) * (YMEM(J) - MEAN))
3060        IF YMEM(J) < MINI THEN MINI=YMEM(J)
3080        IF YMEM(J) > MAXI THEN MAXI=YMEM(J)
3100       NEXT J
3120      VARI=VARI/COUNT
3140      STDDEV=SQR(VARI)
3160 REM
3180 REM
3200 REM  "Print and store the results
3220     PRINT " "
3240     PRINT "              FOR THE ABOVE PEAKS"
3260     PRINT USING "     The average time is          ###.###";TIMT
3280     PRINT USING "     The average value is         ###.###";MEAN
3300     PRINT USING "     The standard deviation is    ###.###";STDDEV
3320     PRINT USING "     The minimum value is         ###.###";MINI
3340     PRINT USING "     The maximum value is         ###.###";MAXI
3360 REM
3380    LPRINT " "
3400    LPRINT "              FOR THE ABOVE PEAKS"
3420    LPRINT USING "     The average time is          ###.###";TIMT
3440    LPRINT USING "     The average value is         ###.###";MEAN
3460    LPRINT USING "     The standard deviation is    ###.###";STDDEV
3480    LPRINT USING "     The minimum value is         ###.###";MINI
3500    LPRINT USING "     The maximum value is         ###.###";MAXI
3520    LPRINT USING "     The laser intensity is  ########.###";LASER
3540 REM
3560    WRITE #1,TIMT,MEAN,STDDEV,MINI,MAXI
3580     WRITE #1,LASER
3600 REM
3620 REM
3640 REM " Close file and disable GPIB"
3660      CLOSE #1
3680      V%=0 : CALL IBSRE(GPIB0%,V%)
```

```
3700 REM
3720 REM                  "END PROGRAM"
3740      END
```

P R O F I L E

```
CLEAR   ,57996!
IBINIT1 = 57996!
IBINIT2 = IBINIT1 + 3
BLOAD "BIB.M",IBINIT1
CALL IBINIT1(IBFIND,IBSTOP,IBTRG,IBCLR,IBPCT,IBSIC,IBLOC,
         IBPPC,IBBNA,IBONL,IBRSC,IBSRE,IBRSV,IBPAD,
         IBSAD,IBIST,IBDMA,IBEOS,IBTMO,IBEOT)
CALL IBINIT2(IBGTS,IBCAC,IBWAIT,IBPOKE,IBWRTF,IBWRTA,IBWRT,
         IBCMDA,IBCMD,IBRDF,IBRDA,IBRD,IBRPP,IBRSP,
         IBDIAG,IBXTRC,IBSTA%,IBERR%,IBCNT%)
REM The following declarations may optionally be included in the user
  application program.  They provide appropriate mnemonics by which
REM to reference commonly used values.  Some mnemonics (GET%, ERR%,
 END%, ATN%) are preceded by "B" in order to distinguish them from
    BASICA keywords.
REM
REM GPIB Commands
REM
UNL% = &H3F      ' GPIB unlisten command
UNT% = &H5F      ' GPIB untalk command
GTL% = &H1       ' GPIB go to local
SDC% = &H4       ' GPIB selected device clear
PPC% = &H5       ' GPIB parallel poll configure
BGET% = &H8      ' GPIB group execute trigger
TCT% = &H9       ' GPIB take control
LLO% = &H11      ' GPIB local lock out
DCL% = &H14      ' GPIB device clear
PPU% = &H15      ' GPIB ppoll unconfigure
SPE% = &H18      ' GPIB serial poll enable
SPD% = &H19      ' GPIB serial poll disable
PPE% = &H60      ' GPIB parallel poll enable
PPD% = &H70      ' GPIB parallel poll disable
REM
REM GPIB status bit vector
REM global variable IBSTA% and wait mask
REM
BERR% = &H8000   ' Error detected
TIMO% = &H4000   ' Timeout
BEND% = &H2000   ' EOI or EOS detected
SRQI% = &H1000   ' SRQ detected by CIC
RQS% = &H800     ' Device needs service
CMPL% = &H100    ' I/O completed
LOK% = &H80      ' Local lockout state
REM% = &H40      ' Remote state
CIC% = &H20      ' Controller-In-Charge
BATN% = &H10     ' Attention asserted
```

```
TACS% = &H8       ' Talker active
LACS% = &H4       ' Listener active
DTAS% = &H2       ' Device trigger state
DCAS% = &H1       ' Device clear state
REM
REM Error messages returned in global variable IBERR%
EDVR% =  0        ' DOS error
ECIC% =  1        ' Not CIC (or lost CIC during command)
ENOL% =  2        ' Write detected no listeners
EADR% =  3        ' Board not addressed correctly
EARG% =  4        ' Bad argument to function call
ESAC% =  5        ' Function requires board to be SAC
EABO% =  6        ' Asynchronous operation was aborted
ENOA% =  7        ' Non-existent board
ESYN% = 10        ' New I/O attempted with old I/O in progress
ECAP% = 11        ' No capability for intended operation
EFIL% = 12        ' File system operation error
EBUS% = 14        ' Bus error
ESTB% = 15        ' Serial poll status byte lost
ESRQ% = 16        ' SRQ remains asserted
REM
REM EOS mode bits
BIN% = &H1000     ' Eight bit compare
XEOS% = &H800     ' Send EOI with EOS byte
REOS% = &H400     ' Terminate read on EOS
REM
REM Timeout values and meanings
REM
TNONE% =   0      ' Infinite timeout (disabled)
T10US% =   1      ' Timeout of 10 us (ideal)
T30US% =   2      ' Timeout of 30 us (ideal)
T100US% =  3      ' Timeout of 100 us (ideal)
T300US% =  4      ' Timeout of 300 us (ideal)
T1MS% =    5      ' Timeout of 1 ms (ideal)
T3MS% =    6      ' Timeout of 3 ms (ideal)
T10MS% =   7      ' Timeout of 10 ms (ideal)
T30MS% =   8      ' Timeout of 30 ms (ideal)
T100MS% =  9      ' Timeout of 100 ms (ideal)
T300MS% = 10      ' Timeout of 300 ms (ideal)
T1S% =    11      ' Timeout of 1 s (ideal)
T3S% =    12      ' Timeout of 3 s (ideal)
T10S% =   13      ' Timeout of 10 s (ideal)
T30S% =   14      ' Timeout of 30 s (ideal)
T100S% =  15      ' Timeout of 100 s (ideal)
T300S% =  16      ' Timeout of 300 s (ideal)
T1000S% = 17      ' Timeout of 1000 s (maximum)
REM
REM Miscellaneous
REM
S% = &H8
LF% = &HA
REM
```

```
92        REM Application program variables passed to
93        REM GPIB functions
94        REM
95        CMD$ = SPACE$(10)        ' command buffer
96        RD$ = SPACE$(255)        ' read buffer
97        WRT$ = SPACE$(255)       ' write buffer
98        BDNAME$ = SPACE$(7)      ' board/device name
99        FILE$ = SPACE$(50)       ' file name
```

```
100                              "PROGRAM PROFILE"
120 REM
140 REM  "The program is used to determine the profile of the
          Charge-Couple Device (CCD) Linear Image Sensor THOMSON-CSF TH7805
160 REM
180 REM   The device has 2048 elements of 13 microns wide
200 REM  Each element integrates the light intensity and outputs a voltage value
          corresponding to the energy detected.
220 REM   The odd elements are sent on channel A
          The even elements are sent on channel B.
          Each element takes 0.703 +/- 0.02 microsec to come out.
240 REM   Channels A and B may be taken independently
260 REM
280 REM   The program starts by a reading the waveform on the scope and finds
           the minimum value, which corresponds to the element response to the
           laser illumination. From that value 4 time beans are established.
300 REM   Each bean is 0.16 us wide and is separated by 0.7 us from the
           other bean center of the same channel. Channels A and B are
           interleaved by half a separation.
320 REM
340 REM   Once the beans are established, the program
360 REM              - Reads a waveform
380 REM              - Finds the minimum value for each bean
400 REM              - Stores each value in a separate vector
420 REM              - Moves the translator one step
440 REM              - Starts over for 80 translator steps.
460 REM
480 REM
500 REM
520 REM "define space allocation for different parameters"
540       ADNAME$ = SPACE$(7)      'GPIB board name
560       DEVNAME$ = SPACE$(7)     'device name
580       DIRA$=SPACE$(20)          'filename on drive a:\gain for output results
600       DIM VALA(150) : DIM VALB(150)
620       TIMDEL$=SPACE$(30)
640       WAVE$=SPACE$(255) : WAVEA$=SPACE$(255) : WAVEB$=SPACE$(255)
660       YA$=SPACE$(128)  :  YB$=SPACE$(128)
```

```
680      XI$=SPACE$(128) : XIT$=SPACE$(12)
700      XO$=SPACE$(128) : XOT$=SPACE$(12)
720      YI$=SPACE$(128) : YIT$=SPACE$(12)
740      YO$=SPACE$(128) : YOT$=SPACE$(12)
760      FILE1$=SPACE$(40)
780      FILE2$=SPACE$(40)
800      FILE3$=SPACE$(40)
820      FILE4$=SPACE$(40)
840      FILE5$=SPACE$(40)
860      FILE6$=SPACE$(40)
880      FILE7$=SPACE$(40)
900      FILE8$=SPACE$(40)
920 REM
940 REM
960 REM          ***************************************************
980 REM
1000 REM                           "INITIALIZATION"
1020 REM
1040 REM   "Questions to be answered"
1060      PRINT "enter initial time delay"          : INPUT TEMPS
1080      PRINT "enter dark signal scope unit for channel A " : INPUT AVGA
1100      PRINT "enter dark signal scope unit for channel B " : INPUT AVGB
1120      PRINT "Which directory of DRIVE A are the data going to?":INPUT DIRA$
1140      PRINT "Enter Volt/division being used" : INPUT VOLTDIV
1160       PRINT "enter maximum voltage response in channel A" : INPUT MAXRESPA
1180       PRINT "enter maximum voltage response in channel B" : INPUT MAXRESPB
1200 REM
1220 REM   "define different parameters
1240      NUMPTS=128    'number of data points to keep
1260      STEPMAX=20
1280       VDIV = (4*VOLTDIV)/128
1300 REM
1320 REM   "initialize gpib adapter and devices
1340      ADNAME$="GPIB0"        : CALL IBFIND(ADNAME$,GPIB0%)
1360      DEVNAME$="SCOPE"       : CALL IBFIND(DEVNAME$,SCOPE%)
1380      DEVNAME$="UNIDEX"      : CALL IBFIND(DEVNAME$,UNIDEX%)
1400 REM
1420 REM   "set gpib0 controller in charge
1440      CALL IBSIC(GPIB0%)
1460      V%=1 : CALL IBSRE(GPIB0%,V%)
1480 REM
1500 REM  "set the scope parameters for the acquisition process"
1520      WRT$="acq;type2;count8;comp100;poin256" : CALL IBWRT(SCOPE%,WRT$)
1540 REM
1560 REM  "set the unidex parameters"
1580      WRT$="G10G91G61G24CRLF" :CALL IBWRT(UNIDEX%,WRT$)
1600      CALL IBRSP(UNIDEX%,RSP%)
1620 REM
1640 REM  "set the initial time delay"
1660      TIMDEL$ = "tim del " + MID$(STR$(TEMPS),2,6) + "e-6"
1680      CALL IBWRT(SCOPE%,TIMDEL$)
1700 REM
```

```
1720 REM  "open files to store maximum value of each detector element"
1740      FILE1$ = "a:\" + DIRA$ + "\elea1.dat" : OPEN FILE1$ FOR OUTPUT AS #1
1760      FILE2$ = "a:\" + DIRA$ + "\elea2.dat" : OPEN FILE2$ FOR OUTPUT AS #2
1780      FILE3$ = "a:\" + DIRA$ + "\elea3.dat" : OPEN FILE3$ FOR OUTPUT AS #3
1800      FILE4$ = "a:\" + DIRA$ + "\elea4.dat" : OPEN FILE4$ FOR OUTPUT AS #4
1820      FILE5$ = "a:\" + DIRA$ + "\eleb1.dat" : OPEN FILE5$ FOR OUTPUT AS #5
1840      FILE6$ = "a:\" + DIRA$ + "\eleb2.dat" : OPEN FILE6$ FOR OUTPUT AS #6
1860      FILE7$ = "a:\" + DIRA$ + "\eleb3.dat" : OPEN FILE7$ FOR OUTPUT AS #7
1880      FILE8$ = "a:\" + DIRA$ + "\eleb4.dat" : OPEN FILE8$ FOR OUTPUT AS #8
1900 REM
1920 REM
1940 REM
1960 REM         **************************************************
1980 REM
2000 REM                   "ANALYSIS OF THE TIME BEANS"
2020 REM
2040 REM  "initial acquisition on channel a to set up parameters"
2060 REM     "read the averaged waveform"
2080        YMIN=127
2100         WRT$="dig1": CALL IBWRT(SCOPE%,WRT$)
2120         WRT$="head0 wave src1 form2 data?" : CALL IBWRT(SCOPE%,WRT$)
2140         CALL IBRD(SCOPE%,WAVE$)
2160         FOR K=3 TO NUMPTS-1
2180          Y$=MID$(WAVE$,2*K-1,1) : Y%=ASC(Y$)
2200          Z$=MID$(WAVE$,2*K,1)   : Z%=ASC(Z$)
2220          YZ= Y% + (Z%/256)
2240          IF YZ > YMIN THEN 2300
2260           YMIN = YZ
2280           MINPOS=K
2300         NEXT K
2320 REM
2340      IF YMIN < 60 THEN 2480
2360      WRT$="X1F5CRLF":CALL IBWRT(UNIDEX%,WRT$) : CALL IBRSP(UNIDEX%,RSP%)
2380       FOR I= 1 TO 1000
2400        K=1+1
2420       NEXT I
2440      GOTO 2000
2460 REM
2480 REM  "minimum is satisfactory, read scope paramters and evaluate
2500 REM     time division for each element
2520     WRT$="head1 xinc?" : CALL IBWRT(SCOPE%,WRT$) : CALL IBRD(SCOPE%,XI$)
2540     WRT$="head1 xor?"  : CALL IBWRT(SCOPE%,WRT$) : CALL IBRD(SCOPE%,XO$)
2560     WRT$="head1 yinc?" : CALL IBWRT(SCOPE%,WRT$) : CALL IBRD(SCOPE%,YI$)
2580     WRT$="head1 yor?"  : CALL IBWRT(SCOPE%,WRT$) : CALL IBRD(SCOPE%,YO$)
2600     XIT$=MID$(XI$,7,12) : XI=VAL(XIT$)
2620     XOT$=MID$(XO$,7,12) : XO=VAL(XOT$)
2640     YIT$=MID$(YI$,7,12) : YI=VAL(YIT$)
2660     YOT$=MID$(YO$,7,12) : YO=VAL(YOT$)
2680 REM
2700     MINTIM = XO + (MINPOS*XI)
2720     TA1=MINTIM - 7.8E-07
2740     TA2=MINTIM - 6.2E-07
```

```
2760       TA3=MINTIM - 8E-08
2780       TA4=MINTIM + 8E-08
2800       TA5=MINTIM + 6.2E-07
2820       TA6=MINTIM + 7.8E-07
2840       TA7=MINTIM + 1.32E-06
2860       TA8=MINTIM + 1.48E-06
2880       TB1=MINTIM - 4.8E-07
2900       TB2=MINTIM - 3.2E-07
2920       TB3=MINTIM + 2.2E-07
2940       TB4=MINTIM + 3.8E-07
2960       TB5=MINTIM + 9.2E-07
2980       TB6=MINTIM + 1.008E-06
3000       TB7=MINTIM + 1.62E-06
3020       TB8=MINTIM + 1.78E-06
3040 REM
3060 REM
3080 REM
3100 REM          **************************************************
3120 REM                       "RECORDING ELEMENT PROFILE"
3140 REM
3160 REM
3180 REM
3200     FOR POSI = 1 TO 80
3220 REM
3240 REM                           DATA ACQUISITION
3260 REM
3280 REM  "initialization"
3300      FOR I= 1 TO NUMPTS
3320       VALA(I)=0
3340       VALB(I)=0
3360      NEXT I
3380      YMA1=128 : YMA2=128 : YMA3=128 : YMA4=128
3400      YMB1=128 : YMB2=128 : YMB3=128 : YMB4=128
3420 REM
3440 REM  "digitzation and average
3460          WRT$="dig1": CALL IBWRT(SCOPE%,WRT$)
3480          WRT$="head0 wave src1 form2 data?" : CALL IBWRT(SCOPE%,WRT$)
3500          CALL IBRD(SCOPE%,WAVEA$)
3520 REM
3540          WRT$="dig2": CALL IBWRT(SCOPE%,WRT$)
3560          WRT$="head0 wave src2 form2 data?" : CALL IBWRT(SCOPE%,WRT$)
3580          CALL IBRD(SCOPE%,WAVEB$)
3600 REM
3620          FOR K=3 TO NUMPTS-1
3640           K1 =  2*K
3660 REM
3680           YA1$=MID$(WAVEA$,K1-1,1) :YA1%=ASC(YA1$)
3700           YA2$=MID$(WAVEA$,K1,1) :YA2%=ASC(YA2$)
3720           VALA(K-2)=YA1% + (YA2%/256)
3740 REM
3760           YB1$=MID$(WAVEB$,K1-1,1) :YB1%=ASC(YB1$)
3780           YB2$=MID$(WAVEB$,K1,1) :YB2%=ASC(YB2$)
```

```
3800           VALB(K-2)=YB1% + (YB2%/256)
3820          NEXT K
3840 REM
3860 REM
3880 REM
3900 REM                        FIND MINIMUM FOR EACH ELEMENT
3920 REM
3940 REM "for each time division corresponding to an element
3960 REM   "find the minimum and its time position"
3980      FOR I = 1 TO NUMPTS-2
4000       TMPS = XO + ( I * XI)
4020 REM
4040       IF TMPS < TA1 THEN 4160
4060       IF (TA1<=TMPS) AND (TMPS<=TA2) THEN 4300
4080       IF (TA3<TMPS) AND (TMPS<=TA4) THEN 4400
4100       IF (TA5<TMPS) AND (TMPS<=TA6) THEN 4500
4120       IF (TA7<TMPS) AND (TMPS<=TA8) THEN 4600
4140 REM
4160       IF TMPS<TB1 THEN 5060
4180       IF (TB1<=TMPS) AND (TMPS<=TB2) THEN 4680
4200       IF (TB3<TMPS) AND (TMPS<=TB4) THEN 4780
4220       IF (TB5<TMPS) AND (TMPS<=TB6) THEN 4880
4240       IF (TB7<TMPS) AND (TMPS<=TB8) THEN 4980
4260       GOTO 5060
4280 REM
4300       IF YMA1 < VALA(I) THEN 4160
4320        YMA1 = VALA(I)
4340        YPA1 = TMPS * 1000000!
4360        GOTO 4160
4380 REM
4400       IF YMA2 < VALA(I) THEN 4160
4420        YMA2 = VALA(I)
4440        YPA2 = TMPS * 1000000!
4460        GOTO 4160
4480 REM
4500       IF YMA3 < VALA(I) THEN 4160
4520        YMA3 = VALA(I)
4540        YPA3 = TMPS * 1000000!
4560        GOTO 4160
4580 REM
4600       IF YMA4<VALA(I) THEN 4160
4620        YMA4=VALA(I)
4640        YPA4=TMPS*1000000!
4660        GOTO 4160
4680       IF YMB1 < VALB(I) THEN 5060
4700        YMB1 = VALB(I)
4720        YPB1 = TMPS * 1000000!
4740        GOTO 5060
4760 REM
4780       IF YMB2 < VALB(I) THEN 5060
4800        YMB2 = VALB(I)
4820        YPB2 = TMPS * 1000000!
```

```
4840        GOTO 5060
4860 REM
4880       IF YMB3 < VALB(I) THEN 5060
4900        YMB3 = VALB(I)
4920        YPB3 = TMPS * 1000000!
4940        GOTO 5060
4960 REM
4980       IF YMB4<VALB(I) THEN 5060
5000        YMB4=VALB(I)
5020        YPB4=TMPS*1000000!
5040 REM
5060     NEXT I
5080 REM
5100 REM
5120 REM
5140 REM                             STORE DATA
5160 REM
5180     YNORMA=(100/MAXRESPA)*VDIV
5200     YNORMB=(100/MAXRESPB)*VDIV
5220 REM
5240 REM  "find the amplitude of each element peak"
5260     YMA1 = (AVGA -YMA1) * YNORMA
5280     YMA2 = (AVGA -YMA2) * YNORMA
5300     YMA3 = (AVGA -YMA3) * YNORMA
5320     YMA4 = (AVGA -YMA4) * YNORMA
5340     YMB1 = (AVGB -YMB1) * YNORMB
5360     YMB2 = (AVGB -YMB2) * YNORMB
5380     YMB3 = (AVGB -YMB3) * YNORMB
5400     YMB4 = (AVGA -YMB4) * YNORMB
5420 REM
5440  PRINT USING" ###.###    ###.###    ###.###    ###.###";YMA1,YMA2,YMA3,YMA4
5460  PRINT USING"     ###.###    ###.###   ###.###  ###.###";YMB1,YMB2,YMB3,YMB4
5480  PRINT " "
5500 REM
5520 REM  "write the results in separate files"
5540     WRITE #1, POSI,YMA1,YPA1
5560     WRITE #2, POSI,YMA2,YPA2
5580     WRITE #3, POSI,YMA3,YPA3
5600     WRITE #4, POSI,YMA4,YPA4
5620     WRITE #5, POSI,YMB1,YPB1
5640     WRITE #6, POSI,YMB2,YPB2
5660     WRITE #7, POSI,YMB3,YPB3
5680     WRITE #8, POSI,YMB4,YPB4
5700 REM
5720 REM
5740 REM                        MOVE THE UNIDEX
5760 REM "move the unidex x translator and wait to settle"
5780     WRT$="X1F5CRLF" : CALL IBWRT(UNIDEX%,WRT$): CALL IBRSP(UNIDEX%,RSP%)
5800      FOR KWAIT = 1 TO 1000
5820       KATTEND = 1+1
5840      NEXT KWAIT
5860 REM
```

```
5880 REM
5900    NEXT POSI
5920 REM
5940 REM
5960 REM         ***************************************************
5980 REM                   "END DATA ACQUISITION LOOPS"
6000 REM
6020 REM  "disable the gpib"
6040     V%=0 : CALL IBSRE(GPIB0%,V%)
6060 REM
6080     CLOSE #1 : CLOSE #2 : CLOSE #3 : CLOSE #4
6100     CLOSE #5 : CLOSE #6 : CLOSE #7 : CLOSE #8
6120 REM
6140 REM                        "END PROGRAM"
6160     END
```

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Photosensitive detectors play a predominant role in data collection procedures of optical signal processing applications. They constitute the transition stage between the optical and electrical portions of the experiment. Among these detectors, linear array image sensors are widely used when high resolution measurements are needed. However, before incorporating these detectors into an experiment, it is important to evaluate their performances. In this report, different tests are presented to allow a characterization of the performance of linear image sensors. The procedures focus on four different aspects of the detectors: the signal structure (including the noise), the sensitivity profile of the detector and the elements and the dynamic range of the detector. As an example, the linear array image sensor TH7805 from Thomson CSF is analyzed.

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